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THE REPORT ON THE DESIGNATION OF NOISE IN ONTARIO

VOLUME I

OCCUPATIONAL HEALTH
AND SAFETY DIVISION

MINISTRY OF LABOUR

November 1982

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NOTE

Because of the fundamental changes made to the proposed regulation following the public meeting on June 24, 1981 the comments received after that time are presented in a separate volume - see volume II. This volume with the exception of the Table of Contents (volume I) and appendices A-I represents the document that was made available for public scrutiny.

THE REPORT ON THE DESIGNATION OF

NOISE IN ONTARIO

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INTRODUCTION

Noise is one of the most common and widely-distributed work place health hazards. It is estimated that approximately 500,000 workers in Ontario are exposed to hazardous levels of noise in the work place.

Exposure to excessive sound energy has long been recognized as a major cause of hearing loss. The development of hearing impairment is often gradual and imperceptible from day to day, but is permanent and irreversible. Since hearing acuity is vital to communication, impairment can interfere with on-the-job safety as well as the normal enjoyment of life.

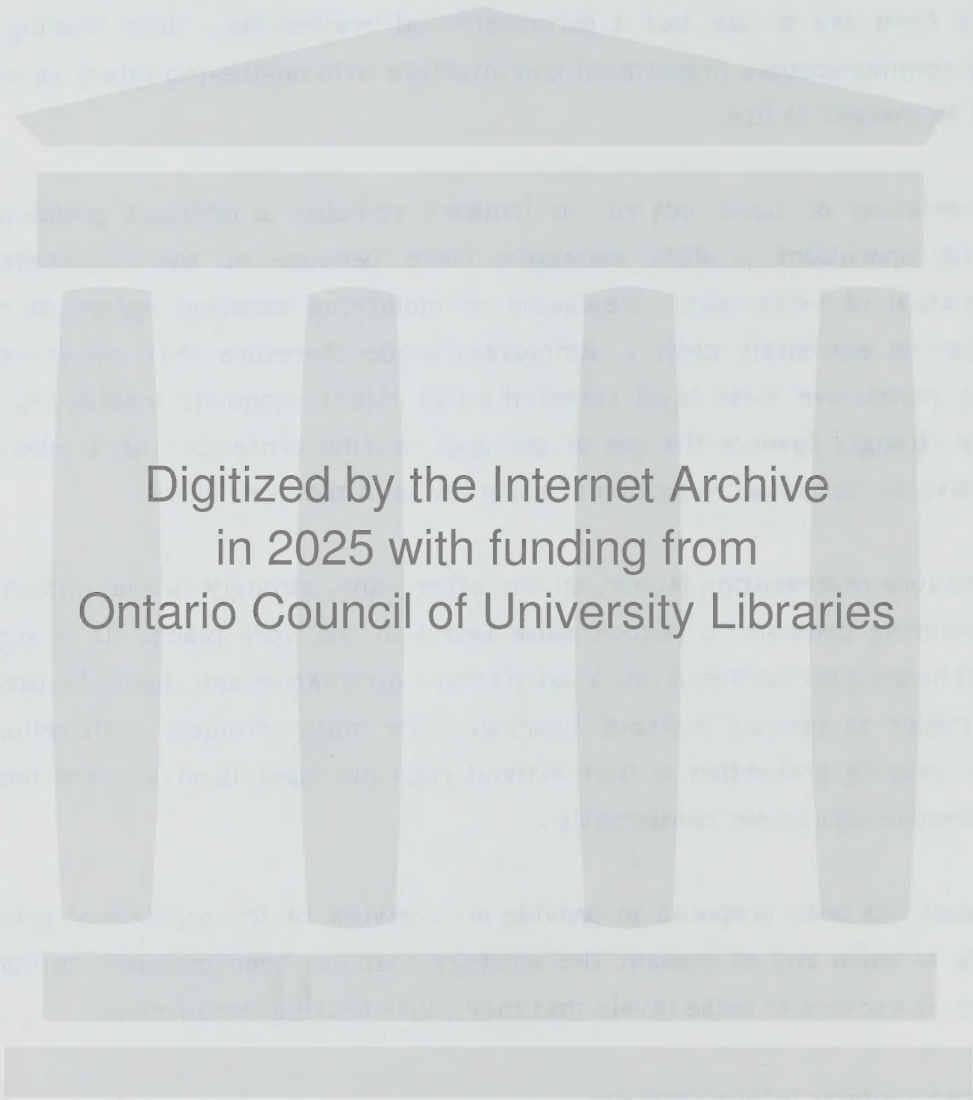
Implementation of noise control in industry remains a difficult problem. Many industrial operations produce excessive noise because of the characteristics or deterioration of equipment. Replacing or modifying existing equipment to reduce noise can be extremely costly. Employers argue therefore that enforcement of a severely restrictive noise level standard could affect economic viability of industry. Industry strongly favours the use of personal hearing protection as a much cheaper alternative to the actual reduction of noise levels in the work place.

Organizations representing labour, on the other hand, strongly favour implementation of engineering controls to reduce noise levels in the work place. It is argued that personal hearing protection is not a satisfactory alternative and should be used only as a last resort to protect workers' hearing. The major problem with reliance upon personal hearing protection is that without rigorous supervision workers tend not to use protective equipment consistently .

This report has been prepared to provide an overview of the problem of occupational exposure to noise and to present the strategy that has been proposed to control the exposure of workers to noise levels that may cause hearing impairment.

The report contains information on:

- measurement of sound and hearing;
- health effects of noise;
- control of occupational exposure to noise;



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- an outline of the proposed regulation published in the Ontario Gazette on August 16, 1980; and
- an analysis of the public comments received in response to the 1980 proposed regulation and the revision presented at the June 24, 1981 public meeting.

The material in the appendices includes the 1980 proposed regulation and code; the 1978 draft regulations and a summary of the comments on the draft regulation for noise received from the public; a document dealing with the health effects of noise exposure prepared by the Special Studies and Services Branch of the Ministry of Labour, and the revisions to the regulation and codes.

Since the original draft noise regulation appeared in 1978, several subsequent versions have been prepared. Changes in the proposed regulation were made in response to both public comments and the recommendations of the Advisory Council on Occupational Health and Occupational Safety (ACOHOS). The numbering of the sections in the regulations was changed in order that those sections dealing with related topics were grouped more closely.

The initially proposed exposure limit of 85 dBA sound level for 8 hours published in the August 1978 draft regulation, met with considerable opposition from industry. In January, 1980 the ACOHOS recommended that the noise regulation be based on a triad of noise level criteria:

i) noise assessment at 80 dBA;

ii) implementation of a hearing conservation program at 85 dBA; and

iii) engineering controls at 90 dBA.

In response to these comments and to updated medical information, the June 24, 1981 proposed regulations specified an "equivalent continuous sound level" limit of 90 dBA.

The new criterion is analogous to a time-weighted average exposure of a worker to noise; it is to be distinguished from the 1978 limit which specified the sound level emitted by the noise source. Additionally, the exchange rate (see discussion under section 4 in chapter 6) was changed from 5 dB to 3 dB and the criterion base period of 8 hours was changed to 40 hours.

The 90 dBA exposure criterion level in the June 24, 1981 proposed regulation is less stringent with respect to the implementation of engineering controls than the 85 dBA exposure criterion specified in the 1980 proposed regulation.

The current proposed regulation has retained this exposure criterion which affords workers increased protection by:

(1) requiring a noise assessment program at sound levels equal to or greater than 80 dBA;

(2) requiring hearing conservation programs when noise levels reach 85 dBA; and

(3) specifying the 3 dB exchange rate which

(a) shortens exposure times, compared to those allowed using the 5 dB exchange rate, at the noise levels above the criterion level of 90 dBA where the risk of hearing impairment is greatest; and

(b) allows for increased exposure times over the base time of 40 hours when the noise level is below the equivalent sound exposure level of 90 dBA where the risk of hearing impairment is lower.

MEASUREMENT OF SOUND AND HEARING

Measurement of Sound

Sound in air is produced by an oscillation in air pressure. These oscillations, or sound waves, are converted to electrical signals by the inner ear and perceived as a sensory experience by the brain. Sound waves may be characterized by their frequency, which is measured in cycles per second (hertz), and by their amplitude or intensity.

Sound intensity is proportional to the square of the pressure fluctuation, which is measured in micropascals (μPa), i.e., $I \propto p^2$. The human ear can hear sounds ranging in intensity from 20 μPa to 200 Pa.

However, sound intensity is usually expressed in decibels (dB). The decibel unit represents 10 times the logarithm, to the base 10, of a sound intensity relative to the threshold of hearing, which is zero dB (Equation 1). A sound 100,000 (10^5) times louder than the threshold value has an intensity of 50 decibels (see Table 1). The threshold of pain is about 140 dB. As decibels are logarithmic units, a doubling of sound intensity is measured as an increase of three decibels.

Equation 1

Definition of Intensity in Decibels

$$I\,(dB) = 10 \log_{10} (p^2/p^2_{ref}) = 20 \log_{10} (p/p_{ref})$$

$I\,(dB)$	is intensity in decibels;
p	is sound pressure in micropascals;
p_{ref}	is a reference sound pressure, the threshold or lower limit of hearing by healthy young ears, equal to 20 μPa.

Because sound waves are actually fluctuations in pressure, p and p_{ref} represent root-mean-square (rms) sound pressure values.

Thus I (dB) is also an expression of root-mean-square sound pressure.

TABLE 1
Relative Sound Pressure Levels Relative to 20 μPa

Relative Sound Pressure	dB	Source
100,000,000,000,000 (10^{14})	140	50 hp siren
10,000,000,000,000 (10^{13})	130	jet takeoff (200')
1,000,000,000,000 (10^{12})	120	rivetting machine casting shakeout area
100,000,000,000 (10^{11})	110	cut-off saw pneumatic peen hammer electric furnace area
10,000,000,000 (10^{10})	100	textile weaving plant subway train boiler room printing press plant
1,000,000,000 (10^{9})	90	pneumatic drill (50') tabulating room inside sport car (50 mph)
100,000,000 (10^{8})	80	freight train (100'), speech (1') vacuum cleaner (10')
10,000,000 (10^{7})	70	near freeway (auto traffic) large store, accounting office
1,000,000 (10^{6})	60	private business office light traffic (100') average residence
100,000 (10^{5})	50	
10,000 (10^{4})	40	soft whisper (5')
1,000 (10^{3})	30	studio (speech)
100 (10^{2})	20	studio for sound pictures
10	10	
1	0	threshold of hearing of youth 1,000 to 4,000 Hz (20 μPa)

The sound levels are at a given distance from sound sources.

A young person can hear sound in the frequency range of 16 Hz to 20,000 Hz. However, the ear is not equally sensitive to all frequencies. Greater intensity is needed for perception of high and low tones, as illustrated in Figure 1. The ear is most sensitive to frequencies occurring between 1,000 and 4,000 Hz.

Continuous Noise and Impulsive Noise

In measuring noise levels, it is necessary to distinguish between two basic types of noise: continuous noise and impulsive or impact noise. The term "continuous noise" is used to mean a steady or uninterrupted noise which is characterized by a relatively constant sound level over a long period of time or during the period of measurement. Impulsive noise means a sharp burst of noise such as that produced upon collision of two metal bodies (as in drop-forging) or by an explosion. If sound from "continous noise", "impulsive noise", or a combination of the two deviates momentarily and perhaps repeatedly from the ambient or background level for a time period of one second or more, the noise is described as intermittent.

Continuous noise is measured with sound level meters. These meters may have several scales which use different sound filter networks to influence their response characteristics. The A-weighted scale has been designed to simulate the response of the normal human ear, which is most sensitive to sounds around 1,000 Hz. Hearing sensitivity falls off at both the high and low ends of the frequency range (Figure 1). Since epidemiological studies have indicated that noise-induced hearing effects correlate well with exposure to noise levels on this scale, noise standards are often specified in A-weighted decibels (dBA's).

Figure 2 shows the frequency response characteristics of a sound level meter using three different filter networks, including the A-scale.

Impulsive noise is a more difficult type of sound to measure because of the rapid and often complicated pressure changes involved. The measurement method widely employed at this time involves the use of a sound meter with a peak-hold capacity which records the maximum intensity of each impulse and the number of impulses during a specified period, allowing for an estimate of total acoustical energy to be made.

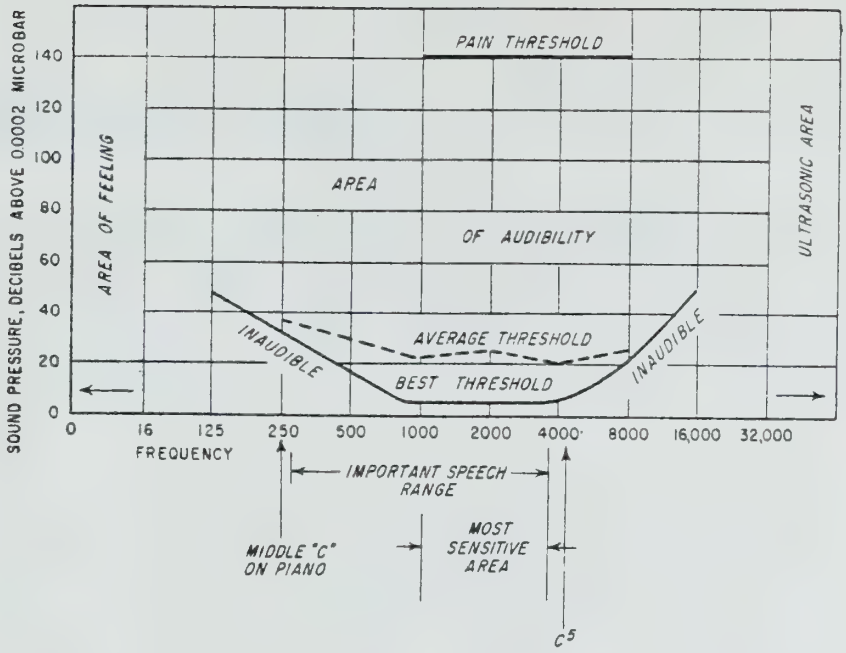

FIGURE 1: The response of the ear to sound - relative intensities (sound pressure) needed for good hearing of tones of varying frequencies. (Source: Finkelstein, M.; 'Background Document on Noise'; March 1, 1979. - see Appendix F).

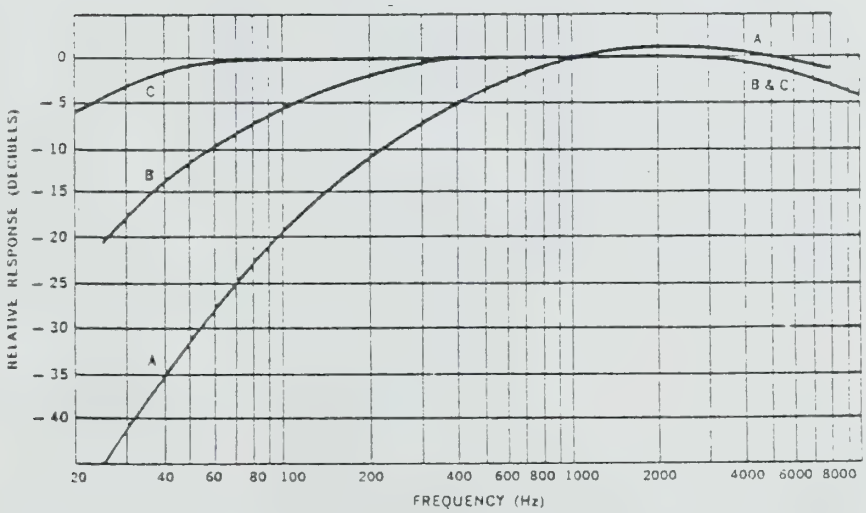

FIGURE 2: Frequency-response characteristics of a sound level meter with A-,B-and C-weighting. (Source: Finkelstein, M.; 'Background Document on Noise'; March 1, 1979. - see Appendix F).

Measurement of Hearing - Audiometry

In a test of hearing, the subject is fitted with earphones and presented with a pure tone of a calibrated intensity at a specified standard frequency. The frequencies used in audiometric testing range between 500 and 8,000 Hz. The threshold audibility, or lowest limit of audibility, at each frequency is determined for each ear by increasing the intensity in 5 dB steps.

The results of the hearing test are then compared with an international standard set down in the International Standards Organization recommendations (R389: ISO, 1964). The threshold values in the recommendations are representative of the modal values of the thresholds of hearing of healthy persons between 18 and 30 years of age, with no history of excessive exposure to noise. These threshold standards are defined as zero and the subject's hearing level is defined as the deviation (in decibels) from the standard of his/her threshold of hearing.

Hearing thresholds vary considerably among individuals. This variability leads to some difficulty in assessing the results of audiometric testing with regard to noise-induced hearing damage. In addition, a number of other factors can complicate the assessment of audiometric results, such as background noise, the condition of the audiometric equipment, and the position and pressure of the earphone on the ear. Studies performed to evaluate the variability of test results due to such factors indicate that, for individuals not exposed to harmful noise, 95% of the audiometric observations of the threshold should fall within ± 8 dB of a person's mean threshold, measured within the range of 500 to 4,000 Hz. This variation is appreciably larger for individuals exposed to potentially hazardous noise.

Representative Sound Levels in Industry

Table 2 contains typical sound levels measured for various industrial operations, grouped under their particular industrial classification. From this table, it can be seen that exposures exceed 85 dBA in the majority of the operations listed.

TABLE 2

Representative Sound Levels in Industries

Industry	Operation	Noise Level (dBA)
Aircraft mfg.	Rivetting	108-114
	Assembly	78
Aluminum forming	Pressing	93
Automotive mfg.	Molding	101-106
	Spray painting	91-104
	Foundry	95-100
Bottling	Washer	94
	Filler	96-100
Chemical	Pebble milling	79
	Fabric coating	79-84
	Kilning	83
	Rubber milling	84-90
	Tire cure press	93
	Gas compressor	88
	Catalytic cracker	102
Construction	Cranes	78-103
	Trucks	83-111
	Rollers	86-110
	Pavers	104
	Pile drivers	106-132
	Rock crushing	94-124
	Diesel generator	103-107
	Grinder	106-113
	Concrete saw	100-116
	Welding	91-104
	Electric drills	90-97
	Table saw	92-110
	Rock drills	104-122
	Sand blasting	104-115
Food processing	Meat chopping	92
	Candy wrapping	84
	Chocolate coating	85
	Canning press	97
	Can conveyor	88-91
Foundry	Electric furnace	105
	Casting cleaning	97
	Grinding	105-110
Furniture	Planing	110
	Jointing, sanding	91
Glass	Bottle forming	98-110
Grain elevator	Axial fan	96
	Dryer	84-93
Hospital	Oxygen tent	85
	Operating room	55-86
Hydroelectric plant	Steam turbine	89-98
	Transformer	83-84
Leather	Hair dryer	86
	Seasoning	76
Logging	Bulldozer	97
	Chain saw	92-105
	Feller shears	93-95
	Log sawing	97
Machinery	Milling, lathing	90
	Drop forging	105
	Punch press	95
	Nail manufacture	100-115
Mining	Jumbo drill	107
	Sloper drill	115
	Continuous mines	99
Paper	Pulp grinding	100
	Paper machine	94
	Drum barker	90
	Carton printer	95
	Shear	97
Printing	Offset press	88
	Linotype machines	73
Quarry		81-102
Refinery		96-103
Steel	Blast furnace	92-94
	Pickler	85-95
Stone	Cutting (48" saw)	92
	Clay crusher	91
Textiles	Spinner frames, combing, cording	80
	Weaving	100
	Sewing	80
	Looms	92-106
Transport	Truck driving	89
	Subway (20-ft.)	90
	Jet airplane (500-ft.)	115

HEALTH EFFECTS OF NOISE*

The effects of noise exposure upon hearing, the characteristics of both temporary and permanent hearing impairment, and methods of predicting the impact on hearing of various levels of noise exposure are discussed in this section. Preceding this discussion is a brief explanation of the operation of the human ear, the effects of age on hearing, and the non-auditory effects of noise exposure.

Anatomical Basis of Hearing

The anatomical basis of hearing is illustrated in Figure 3, where the ear has been schematically divided into three main parts. In the external ear air pressure fluctuations are conducted to the eardrum via the external auditory canal. In the middle ear, these pressure variations are converted into mechanical motion and transferred to the inner ear, which is located within the bones of the head. The mechanical motion is then converted into electrical energy for transmission to the brain. Excessive noise damages the organ of Corti in the cochlea, destroying cells in this organ and interfering with the transmission of nervous impulses to the brain.

Hearing Impairment Due To Age

The deterioration of hearing with age is known as presbycusis. As illustrated in Figure 4, hearing deteriorates initially and most rapidly at the higher frequencies, with impairment at lower frequencies following in later years.

It is currently believed that the effects of age and excessive noise on hearing are independent and additive. This proposition is based largely upon observations that a significant component of presbycusis is associated with changes in the middle ear. The inner ear is the region affected by excessive noise.

It is generally maintained therefore that the subtraction of a presbycusis allowance from measured hearing levels is an acceptable practice in estimating the effect of noise exposure on hearing. This practice is followed by the Workmen's Compensation Board in settling claims for occupationally-induced hearing impairment; 0.5 dB is subtracted for each year of age over 60 years.

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* A more comprehensive treatment of the health effects of noise is contained in a paper prepared by the Special Studies and Services Branch of the Occupational Health and Safety Division (see Appendix F).

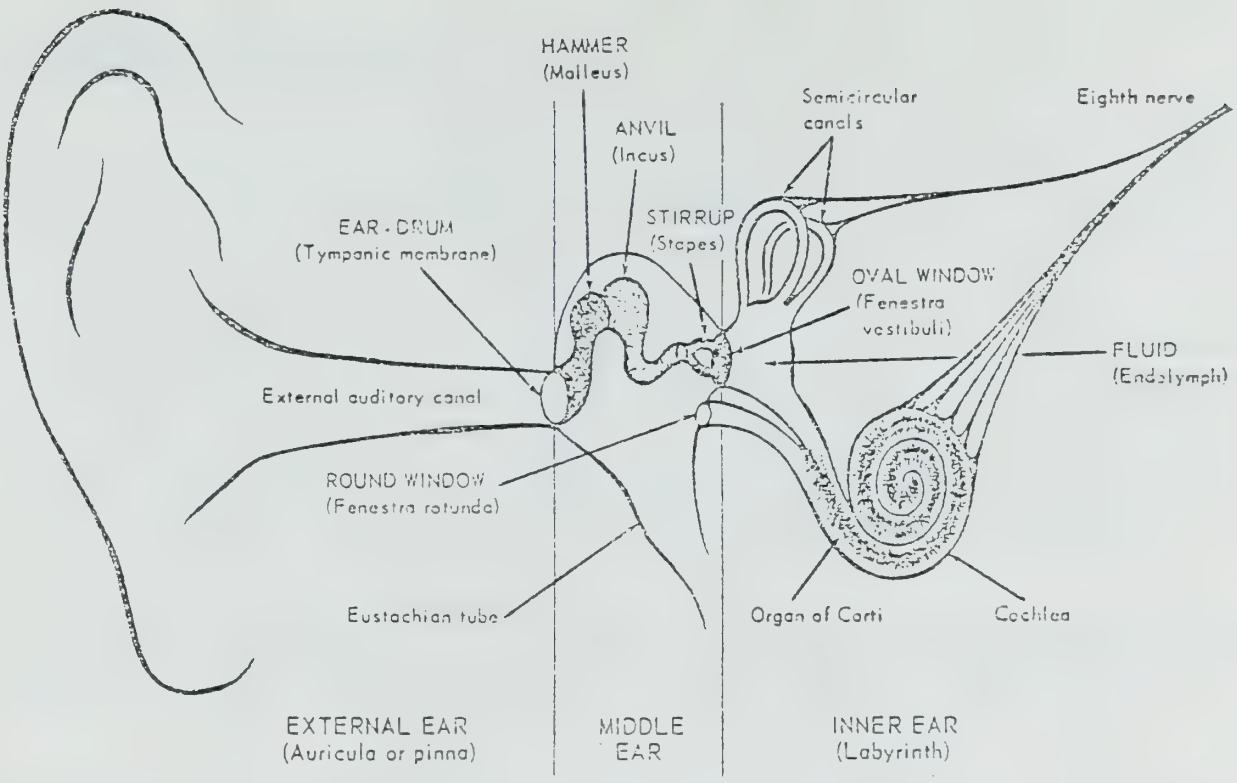

FIGURE 3: Schematic diagram of the ear (Source: Finkelstein, M.; 'Background Document on Noise'; March 1, 1979: see Appendix F).

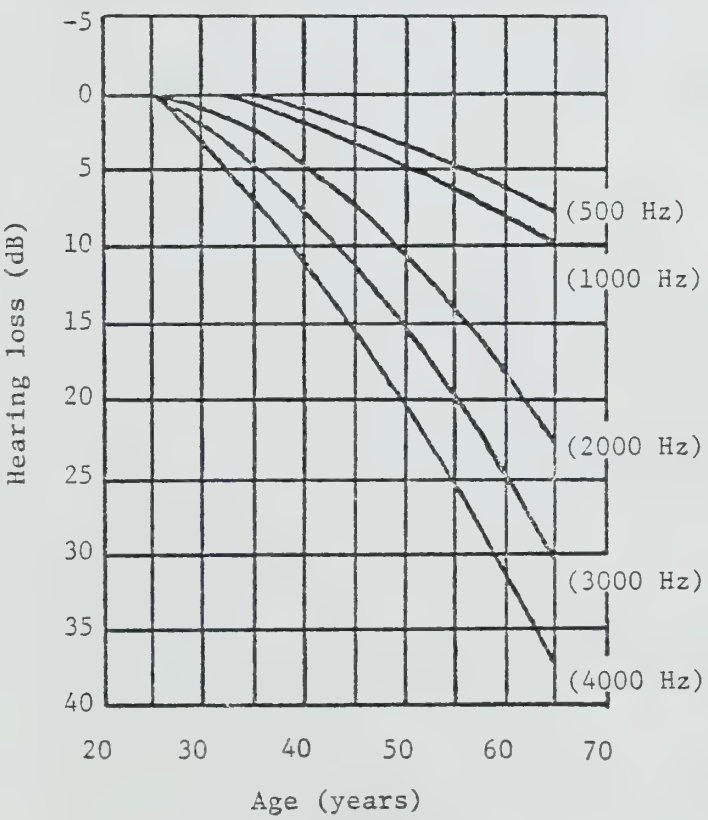

FIGURE 4: Presbycusis curves for men: average hearing loss at different frequencies to be expected with age. (Source: Finkelstein, M.; 'Background Document on Noise'; March 1, 1979: see Appendix F).

Non-Auditory Health Effects

The major concern about non-auditory health effects of noise centres upon the role of noise as a general biological stressor. As a possible source of stress, noise may contribute to a large number of common cardiovascular and other maladies.

One specific area of concern has been explored in a preliminary study of Swedish auto-workers.(1) The mean blood pressures in a group of workers with noise-induced hearing disabilities were higher than those of a group with normal hearing. From such data it has been postulated that prolonged exposure to excessive noise causes repeated rises in blood pressure and may eventually lead to a premanent elevation in blood pressure.

A number of psychological effects also have been attributed to noise in the work place. Possible manifestations of the psychological effects of noise include annoy-ance, lower work performance, absenteeism, and higher injury rates.(2)

However, while noise may indeed be a contributing factor to the above problems, they often have several complex causes, and it is extremely difficult to determine the specific effect of excessive noise. Hearing loss is at present the only directly measurable health effect associated with noise exposure. The focus of this report is therefore on the risk of hearing impairment as the basis for the regulation of worker exposure to noise.

Hearing Impairment Due To Noise Exposure

Damage to hearing is characterized by a decreased ability to hear sounds of low intensity. These changes are measured as the shift of the subject's threshold of hearing relative to the ISO standard.(3) As explained above, the ISO standard has been established as an audiometric reference, representing the threshold of hearing for "normal" young adults. Threshold shifts are defined as the deviation of an individual's hearing threshold from this standard, measured in decibels.

Noise may cause either a temporary or permanent threshold shift in hearing. Both temporary threshold shifts (TTS) and permanent threshold shifts (PTS) are discussed below.

Noise-Induced Temporary Threshold Shift

Excessive noise exposure can strain or "fatigue" the nerve fibres of the ear, impairing the transmission of sensory impulses to the brain and causing a temporary threshold shift (TTS). This type of reduction in hearing ability is reversible since periods of "effective quiet" (76 dBA or less) allow hearing recovery to pre-exposure levels.[3]

It has been shown that:

(i) a greater TTS is produced by higher frequencies of sound within the audible range;

(ii) an increased TTS is noted as both the intensity and duration of the noise is increased;

(iii) TTS is generally less for fluctuating sound than for continuous sound because the intermittent silent periods allow the ear to recover.

Recovery from TTS is delayed when exposure to noise is long and intense or if the TTS induced is greater than 40 dBA. Beyond this point permanent damage may occur. However, the relationship between temporary and permanent threshold shifts in hearing ability remains a matter of controversy. Considerable efforts have been made to discover a relationship between susceptibility to TTS and the development of permanent noise-induced hearing damage. Such a relationship could allow the detection of particularly susceptible individuals. Unfortunately, it has not been shown that susceptibility to temporary threshold shifts indicates a similar susceptibility to permanent hearing impairment.

Apart from its relationship to permanent hearing loss TTS may affect a worker's enjoyment of leisure activities, if the recovery time extends beyond the working day. The effect of such delayed recovery on older workers and workers with damaged hearing could be especially significant.

Noise-Induced Permanent Threshold Shift

A permanent threshold shift (PTS) can be caused either by acoustic trauma, such as gunfire, or by prolonged exposure to excessive noise. The susceptibility of individuals to PTS varies considerably. In a given environment, some individuals may suffer extensive hearing loss while others may be only minimally affected.

It has been shown that:

(i) PTS increased with higher levels of noise and longer periods of exposure;

(ii) PTS occurs at different rates at various auditory frequencies.

Both of these points are discussed below.

(i) Noise Immission

Both the intensity and duration of noise levels are considered to be factors in producing permanent threshold shifts in hearing. In an attempt to quantify the relationship between these two factors and PTS, Burns and Robinson[4] developed a measure of total acoustical energy, termed "noise immission" (equation 2).

Equation 2

Definition of Noise Immission

$$E\ (dBA) = L + 10 \log_{10} T$$

E (dBA)	is the noise immission;
L	is the sound level measured in dBA;
T	is the exposure time in years.

Permanent hearing loss is considered to be related to "noise immission" for exposure greater than one month's duration. This relationship is illustrated in Figure 5, which shows the deterioration of hearing with increasing periods of exposure and levels of noise. Values are calculated from Burns and Robinson.[4] Curves show changes for each A-weighted sound level of occupational noises measured at a frequency of 4,000 Hz.[4]

Since hearing damage is related to both the intensity and duration of noise exposure, it follows that a trade-off relationship exists between these two factors in the regulation of noise exposure. This trade-off relationship means that the risk of noise-induced hearing damage can be controlled by reducing the period of exposure, as well as by reducing the intensity of noise levels.

(ii) The 4,000 Hz Notch

Permanent hearing damage reduces an individual's ability to hear various auditory frequencies. The rate at which this loss occurs depends on the frequency, as illustrated in Figure 6. It can be seen that hearing losses at 3,000 and 4,000 Hz occur first, increase quickly, and then continue at a slower rate. Impairment at lower auditory frequencies occurs much less rapidly and at a more constant rate. This means that the ability to hear frequencies of 3,000 Hz and especially 4,000 Hz is impaired by noise exposure long before the ability to hear other frequencies is affected.

In auditory testing, therefore, PTS first appears as a dip or "notch" at 4,000 Hz relative to a normal hearing pattern. With increased exposure to noise, this loss of sensitivity at 4,000 Hz increases, and the notch broadens to include frequencies in the range of 3,000 to 6,000 Hz. Upon further damage, hearing loss spreads to frequencies beyond the 3,000 to 6,000 Hz range and becomes apparent to the subject. In the early stages, sounds like the letter "S" will not be heard, although the letter "O" will. As damage progresses, words like "fifteen" and "sixteen" become indistinguishable. In later stages, word comprehension is lost even though a sound is still heard.

The 4,000 Hz notch may be used to identify workers whose hearing is particularly sensitive to noise-induced damage, since it is expected that the "notch" will show up in the audiograms of such individuals before other less sensitive workers exhibit this sign of impairment. Appearance of this notch in the audiograms of a number of workers at a particular work place would signal the need for increased hearing protection measures, either in the form of engineering controls or personal hearing protection.

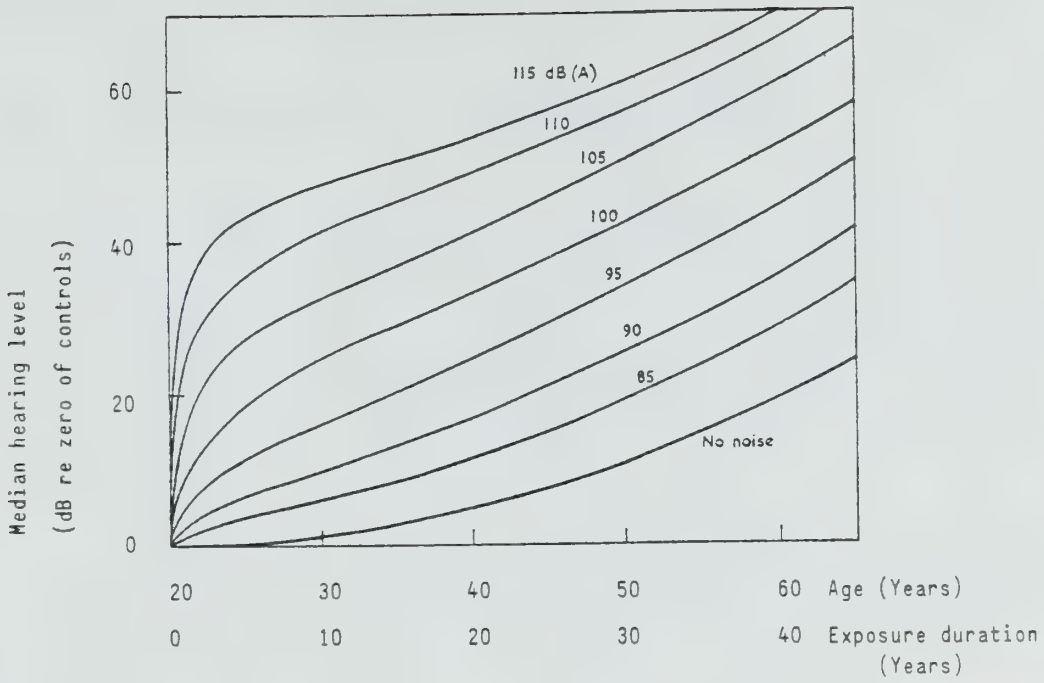

FIGURE 5: Development of hearing deteriorization as a result of age and noise exposure. (Source: Finkelstein, M.; 'Background Document on Noise'; March 1, 1979 - see Appendix F).

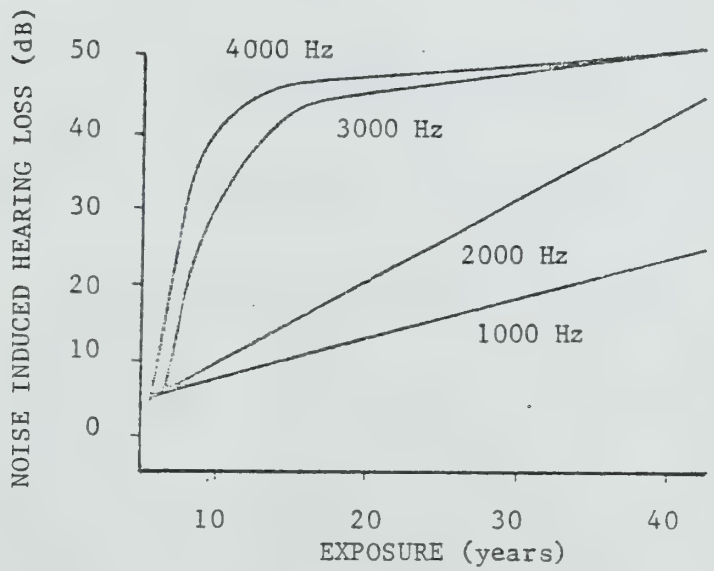

FIGURE 6: Development of noise-induced hearing loss at indicated test frequencies as a function of duration of occupational exposure. These curves have been simplified and smoothed to illustrate the pattern of hearing loss development. The numbers are not precise. (Source: Finkelstein, M.; 'Background Document on Noise'; March 1, 1979 - see Appendix F).

Implementation of such measures at this time could remove the risk of hearing damage before hearing becomes noticeably impaired.

Estimating the Effect on Hearing of Continuous Noise Exposure

Burns and Robinson developed an equation which predicts the effects of continuous noise on a population of workers, rather than on an individual. This approach is useful given the high degree of individual variability. Their equation was developed from a study of British industrial workers that forms the basis of the British Occupational Hygiene Society standard concerning occupational noise exposure. A total of 759 workers with one month to 50 years of exposure to noise in the work place was selected after exclusion of workers with any otologic disease.

Figure 5 shows the effect of age, duration of exposure, and sound levels on hearing. Burns and Robinson found that such curves could be reproduced for specific groups using Equation 3.

Equation 3

The Burns-Robinson Equation

$$H_p = 27.5 \left[1 + \tanh \frac{E - F_f + U_p}{15} \right] + U_p$$

H_p is the hearing loss equalled or exceeded by p% of the population and has been corrected for age effects or presbyacusis;

E is the acoustic energy received as defined by the noise immission equation (Equation 1) in units of dBA;

F_f is a constant which depends on the audiometric frequency at which hearing is being tested;

U_p is a constant depending on p% of the population being considered.

F_f and U_p are two adjustable parameters. Tables of these values have been published.[5] (Note: A correction of 1.5 dB is added to F for women and subtracted from F for men, since male hearing is apparently more sensitive to noise.)

Using this equation, one may predict the level of hearing damage at any given auditory frequency for a percentage of the population, given the total sound energy to which this population has been exposed. The total sound energy is determined from the noise immission equation (Equation 2), using the noise levels to which the subjects were exposed and the duration of the exposure to these levels.

The Relationship Between Noise Exposure and Hearing Loss

In the past 15 years, several major industrial studies have been conducted in an attempt to discover the relationship between noise exposure and hearing loss. As a result of these studies, it has become possible to predict with some confidence the effects of various levels of noise exposure on a population of exposed workers, although individual risk assessment remains difficult due to differences in individual susceptibility to noise-induced hearing damage. The findings of this research form the basis of the proposed regulatory standards for occupational exposure to both continuous or intermittent noise and impact or impulsive noise.

85 dBA and 90 dBA

There is substantial evidence that exposure to noise levels at 90 dBA over a working lifetime can cause a significantly greater degree of hearing loss than exposure to 85 dBA. Recent studies which have led to this conclusion include those of Passchier-Vermeer,[6] Baughn,[7] Burns and Robinson,[4] Johnson,[8] and the National Institute for Occupational Safety and Health (NIOSH)[9]. The Inter-Industry Noise Study[10] has been excluded from this summary of the health effects of noise. The critique of this study appears in the more complete background document on health effects of noise (Appendix F). This brief discussion considers only the three studies most relevant, namely those by Burns and Robinson[4], Johnson[8], and NIOSH[9].

1) Burns and Robinson: The industrial study performed by Burns and Robinson in Britain and discussed above forms the basis for the current British Occupational Hygiene Society standard for wideband noise. The results of this study indicate that approximately 10% to 15% more workers will suffer impaired hearing if exposed to continuous noise of 90 dBA over a working lifetime than if exposure is limited to 85 dBA. Impairment was defined as a hearing loss of 25 dBA or more at age 60, using the average loss measured at the frequencies of 0.5, 1, 2, and 3 kHz. This is the definition of impairment currently used by the Workmen's Compensation Board in Ontario.

The Burns-Robinson equation which was developed on the basis of this study has been introduced. This equation predicts the level of hearing impairment which will result from various levels of noise exposure, as adjusted for presbycusis and several other factors.

TABLE 3

Summary of Permanent Hearing Damage (Noise-Induced Permanent Threshold Shift, NIPTS) Expected for Continuous Noise Exposure at Various Values of the A-Weighted Average Sound Level at 4 kHz or Averaged Over the Range Indicated.

	av. 0.5, 1, 2 kHz	av. 0.5, 1, 2, 4 kHz	4 kHz
80 dBA for 8 hrs.			
Max. NIPTS 90th percentile	1 dB	4 dB	11 dB
NIPTS at 10 years 90th percentile	1 dB	3 dB	9 dB
85 dBA for 8 hrs.			
Max. NIPTS 90th percentile	4 dB	7 dB	19 dB
NIPTS at 10 years 90th percentile	2 dB	6 dB	16 dB
90 dBA for 8 hrs.			
Max. NIPTS 90th percentile	7 dB	12 dB	28 dB
NIPTS at 10 years 90th percentile	4 dB	9 dB	24 dB

TABLE 4

Hearing Impairment Risks Due to Noise Exposure as Estimated by NIOSH and ISO *

Noise Level	Total Percentage Impaired		Percentage "Non-Exposed" Impaired		Percentage Impairment Due to Noise	
dBA	NIOSH	ISO	NIOSH	ISO	NIOSH	ISO
80	23	33	20	33	3	0
85	35	43	20	33	15	10
90	49	54	20	33	29	21

* Note: NIOSH estimate based on workers 55-70 years old, with 21-41 years exposure. ISO estimate based on workers 58 years old with 40 years exposure. Presbycusis effect is subtracted.

2) Johnson: In a study for the United States Environmental Protection Agency, Johnson used the data bases of three previous studies (Passchier-Vermeer,[6] Baughn,[7] and Burns and Robinson[4]) to calculate an average noise effect on hearing. Table 3 contains a summary of Johnson's results which are presented in percentiles. The maximum NIPTS of the 90th percentile is the level of hearing impairment (measured in terms of a threshold shift) not exceeded by 90% of the population after exposure for a working lifetime. It is apparent from these figures that hearing damage is markedly greater for exposure to 90 dBA than that seen for exposure at 85 dBA and that the level of hearing damage associated with exposure at 90 dBA approaches a much more significant level in terms of functional impairment than that indicated at 85 dBA.

3) NIOSH: From 1968 to 1971 NIOSH conducted thirteen surveys to collect data concerning hearing impairment among industrial workers. This data led to the conclusion that at retirement 30 workers in 100 would have impaired hearing following occupational exposure to 90 dBA of continuous sound during the working day, as compared with 15 workers in 100 exposed to noise levels of 85 dBA. Hearing was considered impaired when the average loss over the frequencies 0.5, 1, and 2 kHz was greater than 25 dB. (Note that this is considered a less sensitive indicator than the WCB testing procedures which include the higher frequency of 3 kHz.)

Table 4 summarizes the NIOSH findings. Similar survey results produced by the ISO are also shown.

In addition to the incidence of hearing impairment associated with 85 and 90 dBA, Tables 3 and 4 also present test results on the effect of noise levels at 80 dBA. From these figures it is apparent that the risk of noise-induced hearing loss is less at a level of 80 dBA than at 85 dBA. In fact, it is widely believed that, although 76 dBA is held to be the level of "effective quiet", noise levels may be allowed to reach 80 dBA before extended exposure will generally have any discernible effect upon the ability to hear the important speech frequencies.

Estimating the Effect on Hearing of Impulsive Noise Exposure

Much less is known at present about the effects of impulsive noise on hearing than is known about continuous noise exposure. Indeed, the relationship between impulsive noise exposure and hearing loss remains an area of controversy.

The work of Atherley and Martin is an important contribution to this area.[11] Upon reviewing a number of recent industrial studies relating impact noise exposure to hearing loss, Martin has concluded that the sound energy produced by impact noise will have the same effect on hearing as an equal amount of sound energy produced by steady noise levels.[12] Thus, Martin contends that the principle of "equal energy" can be applied to impulsive noise. According to this principle there is a product relationship between the intensity and duration of noise exposure so that equal amounts of A-weighted sound energy cause equal amounts of damage to hearing regardless of the time pattern or period of time over which that energy is delivered.

By applying this principle to impulsive noise exposure, the Burns-Robinson formula can be used to predict the effect of such exposure on hearing loss. This requires that impulsive noise levels be equated with levels of sound energy produced by continuous noise. Equation 4 illustrates the work of Atherley and Martin in defining the hypothetical continuous sound level that contains the same sound energy as an actual impulsive noise level.

Equation 4

Definition of Equivalent Continuous Sound Level for Impact Noise

Atherley and Martin[10] have shown that:

$L_{eq} = P_h + 10 \log R + 10 \log t_e - 8.6$

L_{eq} is the equivalent continuous sound level;

P_h is the peak height or maximum noise level reached by the sound wave expressed in dBA units;

R is the repetition rate of the pulses;

t_e is the time required for the sound wave to decay to 1/e of its initial height.

Equation 2, which measures "noise immission" or total acoustical energy for continuous sound levels, can be adapted by using the quantity L_{eq} to measure impact noise immission. This is shown in Equation 5.

Equation 5

Definition of Impact Noise Immission

$$E\ (dBA) = L_{eq} + 10 \log T$$

The Burns-Robinson Equation (Equation 3) can then be used to predict the expected hearing loss experienced by a specified percentage of the population for a specified level of impact noise.

Atherley and Martin have shown that predictions obtained from this formulation are generally consistent with actual levels of impaired hearing among workers exposed to impact noise, as observed in a number of industrial studies. However, it is important to note that more data are necessary to establish with certainty the precise relationship between impulsive noise exposure and hearing loss. In particular, additional evidence is required to ascertain whether equal amounts of impulsive and continuous sound energy produce identical effects on hearing. Although a positive relationship between impact noise exposure and hearing loss is certainly indicated, the

intervals of lesser noise intensity between the peak thresholds of impulsive sound may allow the ear to recover to some extent, thereby attenuating the amount of hearing damage sustained at a specified level of sound energy over a specified period. In other words, this application of the "equal energy" principle remains open to doubt because the pattern of sound to which a worker is exposed may be a significant factor in determining the level of risk of hearing impairment.

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CONTROL OF OCCUPATIONAL EXPOSURE TO NOISE

The selection of the optimal strategy for the effective, efficient and equitable control of the exposure of workers to an occupational health hazard is essentially a public policy decision. Frequently, such decisions must be made in an atmosphere of scientific uncertainty and conflicting public policy objectives.

The control of health hazards is based on the assumption that, for each hazard, there exists some safe or tolerable level of exposure. It must be decided which exposures merit control and how and when control should be introduced. Furthermore, a number of factors must also be considered including: the dimensions of the hazard, the evidence as to the risks posed by the hazard, the cost and benefits of control, and the feasibility of implementing various control techniques.

Control Strategies

The adverse effects of occupational exposure to excessive noise can be controlled in a number of different ways. A regulatory strategy for the protection of workers against noise-induced hearing loss may include the following.

Prescribed Limits Setting Out Permissible Levels of Exposure to Sound

Limits on worker exposure to noise may take several forms:

(a) separate levels for continuous and impulsive noise;

(b) ceiling levels above which no worker may be exposed without hearing protection;

(c) levels above which workers are required to wear protective equipment for exposures greater than specified periods of time.

Sound level monitoring is generally required to determine compliance with prescribed limits.

Engineering Controls

Permanent engineering modifications to operations may be required to reduce noise to acceptable levels. Such controls include equipment design modifications, the use of muffling devices, and isolation of noisy operations.

Administrative Controls

Administrative practices that reduce the exposure time of workers may be required. This method of control may be employed where noise levels cannot be immediately reduced to acceptable levels or where protective equipment is inadequate to protect against noise.

Protective Equipment

Personal hearing protection equipment offering various levels of protection is available. Protective equipment may be used as a permanent feature of a control strategy or as a temporary measure in the absence of other types of control.

Medical Surveillance

Medical or audiometric examinations may be required on a periodic basis to detect signs of hearing loss that may be due to occupational noise exposure.

Control of Noise in Foreign Jurisdictions

Table 5 lists the countries which have developed noise regulations. As this table shows, Sweden and the U.S.S.R. are among nations which have implemented an 85-dBA limit whereas other countries such as the United States and Australia allow a 90-dBA limit. Most of the countries listed use the 3 dB exchange rate.

In 1979, in the United States, OSHA revised its Industrial Hygiene Field Operations Manual, which contains instructions to officers enforcing work place health standards. The manual now describes a minimally effective hearing conservation program as including:

TABLE 5

Noise Standards in Other Jurisdictions*

Jurisdiction	Law (L) or Guideline (G)	Existing Limit - dBA (Exchange Ratio - dB)	Mandatory Audiometric Testing	Mandatory Ear Protection
Australia	G	90 (3)		
Austria	L (1974)	85 (3)	If 85 dBA, every 3 years.	
Belgium		90 (3)		
Czechoslovakia		85 (5)		Yes
Denmark	G (1974)	90 (3)		
Finland	L (1974)	85	If 88 dBA, every 3 years. If 100 dBA every year.	
France	L (1975)	90 (3)		Yes
E. Germany	L (1960)	85		Yes
W. Germany	L (1970)	90 (3)		
Netherlands	G In preparation		Yes (details unknown)	Yes (details unknown)
Italy	L (1956)	90 (5)		
Japan	G	90		
Norway	None			
South Africa	L	85 (3)		Yes
Spain				Over 85 dBA
Sweden	G	85 (3)		
Switzerland	G	$90^{+}_{-}2$ (3)		
United Kingdom	G	90 (3)		Over 90 dBA
U.S.S.R.	L	85 (3)		
U.S.A.	L	90 (5)		
Yugoslavia	L (1971)	90 (5)		

* Source: Environmental Health Directorate, Health and Welfare Canada, "Noise Hazard and Control", 1979.

(a) audiograms at the time of employment for workers exposed to sound levels equal to or greater than 90 dBA for an 8-hour day (90 dBA is the current noise level standard for 8 hours of exposure daily);

(b) periodic audiograms for exposed employees;

(c) analysis of audiometric results followed by re-testing and/or referral to an otolaryngologist or qualified physician when a threshold shift of more than 20 dB occurs;

(d) individual fitting and instruction in the use of personal hearing protection.

Control of Noise in Canada

Table 6 contains a summary of noise regulations in those provinces which have legislated maximum noise exposure limits. Alberta has adopted the 85 dBA exposure limit. Saskatchewan has the most comprehensive regulation with provisions for audiometry, noise level monitoring, and hearing protection. British Columbia and New Brunswick are the only provinces which regulate impact noise.

Ontario

Prior to the enactment of The Occupational Health and Safety Act, 1978, S.O. 1978, c.83 the regulation, restriction, limitation and control of occupational hazards were effected in Ontario in various ways by means of three separate statutes and the regulations promulgated thereunder. These were: The Industrial Safety Act, 1971, S.O. 1971, c.43 as amended and O. Reg. 259/72; The Construction Safety Act, 1973, S.O. 1973, c.47 and O. Reg. 419/73; and The Mining Act, R.S.O. 1970, c.274 as amended.

The regulation and control of noise as a hazard to health was dealt with by two distinct approaches. With respect to "industrial establishments" section 3 of O. Reg. 259/72 was enacted. With respect to mining operations governed by The Mining Act, the Ministry of Labour through its Mining Branch established a Noise Code as a guideline for the mining industry.

TABLE 6

Summary of Some Features of The Noise Regulations in Effect in Canada

	Federal	Alta.	Alta. 1979 draft	BC	Man.	NB	Nfld.	NS	PEI	PQ	Sask.
8 hour steady noise limit, dBA	90	85	85	90	85	90	85	85	-	90	85
8 hour impact noise limit, (dB peak SPL)*	140	140	140	140	140	140	140	140	-	140	-
Audiometry required	No	Yes	Yes	Yes	No	No	No	No	No	Yes	Yes
Monitoring required	Yes	No	No	No	No	No	No	No	No	No	Yes
Hearing protection required	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Warning signs required	Yes	No	No	Yes	No	Yes	No	No	No	No	Yes

* permissible number of impluses per day is 100 except in B.C. where it is 90.

A summary of this previous legislation is set out in Appendix H.

A data sheet was issued by the Ministry of Health in 1971 which recommended the implementation of hearing conservation programs (including noise level monitoring) in work places where noise levels presented a potential hazard. This data sheet, which has since been withdrawn, also emphasized the value of audiometric testing for exposed workers.

Policy Consideration

Some of the major considerations to be addressed in the development of a regulatory strategy for the control of occupational exposure to noise are summarized below.

Hazard

The need for improved control of occupational exposure to noise is dramatically illustrated in Ontario by the increase in hearing loss claims allowed by the Workmen's Compensation Board from less than 300 claims allowed in 1971 to more than 2,000 in 1977. More claims are filed for occupational hearing loss than for any other occupational illness.

Research into the effect of variable levels of noise exposure indicates that the risk of incurring hearing loss due to exposure at 90 dBA is considerably greater than at 85 dBA. On the basis of such evidence, NIOSH has recommended that the limit in the United States should be reduced from 90 dBA to 85 dBA.

The ultimate objective of limiting worker exposure to noise is the prevention of hearing "impairment". Definitions of this concept range from "difficulty in communication", about a 50 dB loss, to "minor interference with the enjoyment of leisure activities", probably about a 15 dB loss at speech frequencies. The Workmen's Compensation Board currently considers a hearing loss of 25 dB averaged over several frequencies to constitute impairment for the purposes of assessing claims. It is important to recognize that workers today do not accept hearing impairment as "part of the job" as was often the case in the past.

Control Technology

The necessary technology for the control of noise levels in many types of work place is available although the costs of implementation may be considerable in some cases. However, effective control technology for some work environments currently requires further development and the reduction of noise to a relatively innocuous level does not appear technically feasible in the near future.

Use of Protective Equipment

Personal hearing protection equipment presents an easy and relatively inexpensive method of protecting workers in many work environments. However, the use of such equipment as a central feature of any control program has major drawbacks; the hazard of noise is not reduced or eliminated and worker compliance with protective equipment programs is often poor because of the discomfort or inconvenience caused by the equipment and poor understanding of the hazard. Furthermore, such equipment may be ineffective in high noise situations.

The Royal Commission on the Health and Safety of Workers in Mines

The Report of the Royal Commission on the Health and Safety of Workers in Mines contained a number of recommendations relevant to the development of a strategy for the control of work exposure to noise. In summary, the Commission recommended:

1) noise maps of mines showing areas with noise levels of 85 dBA or more;

2) research on noise exposures in typical occupations, with the resulting job noise exposures recorded for each mine;

3) developent of equipment standards, to be used when acquiring new equipment;

4) a code of practice for personal hearing protection;

5) audiometric records for each miner exposed to 85 dBA or more, keyed to personal exposure records;

6) assessments of miner hearing on a five year cycle;

7) assessments of audiometric facilities.

Advisory Council on Occupational Health and Occupational Safety

Of particular relevance to the establishment of a control strategy for occupational hazards in general are the remarks of the Ontario Advisory Council on Occupational Health and Occupational Safety which appeared in its first annual report, released in 1979.

The Council suggested that:

- a critical resource is the internal reponsibility system of management and labour at each work place;

- effective control strategies depend upon wise use of all the resources available to those at the work place and in charge of the work place;

- it is essential that the implementation of these policies should, wherever possible, be done in a manner which maximizes the self-regulatory and self-compliance philosophy for meeting objectives in occupational health and occupational safety;

- the government should adopt performance standards wherever possible.

In Advisory Memorandum 79-III, "Occupational Hearing Loss: Prevention, Compensation and Rehabilitation", the Advisory Council presented to the Minister of Labour 37 recommendations relating to occupationally induced hearing loss. Specifically, Council recommended that the Ministry should adopt a regulation for the control of noise exposure, providing for:

- periodic measurement of sound in work places with 80 dBA or more,

- audiometric testing of employees exposed to four or more hours of sound at 85 dBA or more,

- employers to provide personal hearing protection devices where employees are exposed to 85 dBA or more,

- employers to reduce sound levels to 90 dBA by whatever means possible and, where this cannot be achieved, to require employees to wear personal protective hearing devices.

The full text of the Council's Memorandum along with the Minister's response are reproduced in Appendix G.

THE AUGUST 16, 1980 PROPOSED REGULATION

The proposed regulation relating to the designation of noise (see Appendix A) under the provisions of The Occupational Health and Safety Act, 1978 was published in The Ontario Gazette on August 16, 1980 as required by section 22(b) of The Act, which reads as follows:

> "Prior to a substance being designated under paragraph 14 of subsection 2 of section 41, the Minister,
>
> (a) shall publish in The Ontario Gazette a notice stating that the substance may be designated and calling for briefs or submissions in relation to the designation; and
>
> (b) shall publish in The Ontario Gazette a notice setting forth the proposed regulation relating to the designation of the substance at least sixty days before the regulation is filed with the Registrar of Regulations. 1978, c.83, s.22."

The notice of intent to designate noise as required by section 22(a) appeared in The Ontario Gazette on June 28, 1980.

The Act permits, in section 41(1), the making of regulations "as are advisable for the health or safety of persons in or about a work place". Sections 41(2) 14 and 41(2) 15, which relate specifically to designated substances, state that the Lieutenant Governor in Council may make regulations:

"14. prescribing any biological, chemical or physical agent or combination thereof as a designated substance;

15. prohibiting, regulating, restricting, limiting or controlling the handling of, exposure to, or the use and disposal of any designated substance;"

On August 19, 1978 a draft regulation with respect to noise was published in The Ontario Gazette in order to encourage public involvement and participation in the development of regulations for the protection of workers against occupational health hazards. The notice covering this publication of the draft regulation invited comments

from the public. The comments received were analysed in detail by Ministry officials to identify the public's reactions to the regulation overall as well as the specific provisions of the draft regulation. In many instances, the written comments that were provided were supplemented by dialogue between Ministry officials and interested parties to clarify issues raised in the briefs. A summary of the comments that were received with respect to noise is presented in Appendix D. The organizations that responded to the publication of the draft regulation are listed in Appendix E.

Most organizations that responded to the notice of intent to designate, reiterated the comments made with respect to the draft regulation that was published in 1978. The comments received on the notice of intent to designate are summarized along with comments that were received on the proposed regulation.

The regulation for noise is based upon the concept of internal responsibility that was enunciated by the Ham Commission and embodied in The Occupational Health and Safety Act, 1978. As drafted, the proposed regulation will involve both employers and workers in the design and implementation of programs that will protect workers against the hazards of exposure to noise in the workplace.

The structure of the August 16, 1980 proposed regulation was developed and the proposed limits were selected following an extensive review of the medical and technical literature, an examination of the regulatory strategies used in other jurisdictions to control worker exposure to noise, analysis of the public commentary on the 1978 draft regulations, and the memorandum on occupational hearing loss prepared by the Advisory Council on Occupational Health and Occupational Safety (see Appendix G).

The regulation will apply to every employer at whose work place a worker is likely to be exposed to noise exceeding the exposures prescribed in Section 4 of the proposed regulation. All employers to whom the regulation applies must conduct an assessment of the actual or likelihood of worker exposure to noise.

When conducting the assessment and developing an appropriate control program, the employer must consult with the joint health and safety committee. Section 8(2) of the Act provides for the establishment of a joint health and safety committee where "a regulation made in respect of designated substance applies to a work place".

If the assessment indicates that any worker is likely to be exposed to levels of noise above the prescribed limits, the employer must develop a control program that includes provision for:

- engineering controls to control worker exposure to noise
- monitoring to determine noise levels
- maintenance of personal exposure records for exposed workers
- medical and audiometric examinations
- maintenance of medical records.

This control program must restrict worker exposure to noise so that the exposure of each worker does not exceed the prescribed limits set out in Section 4 of the proposed regulation. Exposure control must be achieved by means other than the use of personal hearing protection unless an employer establishes to the satisfaction of an inspector that special circumstances exist (see Section 8 of the proposed regulation, Appendix A).

The exposure limits proposed in the August 16, 1980 regulation were selected on the basis of the health effects information currently available in the medical and scientific literature. It must be recognized that these data are imperfect, but an attempt was made to arrive at an assessment of the relationship between noise exposure and the risk of hearing impairment. As a result of this assessment, it was felt that substantial benefit could be conferred upon the population of Ontario workers exposed to noise by lowering the 8 hour exposure limit from 90 dBA to 85 dBA. This action would significantly lower the risk of hearing impairment, a condition with considerable impact upon the quality of life.

In the Advisory Council Memorandum 79-III (January 14, 1980) the recommended 8-hour limit for noise exposure was 90 dBA. The council acknowledged that medical research indicates exposure to a noise level of 90 dBA can result in a greater risk of hearing impairment than occurs at 85 dBA and for this reason, argued that the reduction of noise levels to 85 dBA is a desirable long-term objective. However, the council concluded that for many employers it is not practicable at this time to achieve compliance with this lower level of occupational noise exposure.

The Ministry acknowledged the council's concerns in this regard. The draft regulation on noise, published in August, 1978, proposed an exposure limit of 85 dBA for eight hours of daily exposure on the basis of medical research such as that cited in the council's memorandum. However, prior to formulating a final regulation for occupational noise exposure, the Ministry indicated that it would take into consideration the position adopted by the council which echoes the concerns expressed in many submissions to the Ministry in response to the publication of the draft regulation. As a body representative of both employer and worker interests, the council's support of a 90 dBA limit was weighed carefully in Ministry deliberations on this issue in formulating the final version of the noise regulation.

THE REPORT ON THE DESIGNATION OF NOISE IN ONTARIO

APPENDICES

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APPENDIX A

THE PROPOSED REGULATION
UNDER
THE OCCUPATIONAL HEALTH AND SAFETY ACT, 1978
PUBLISHED IN THE ONTARIO GAZETTE AUGUST 16TH, 1980

NOISE

OCCUPATIONAL HEALTH
AND SAFETY DIVISION

MINISTRY OF LABOUR

MINISTRY OF LABOUR

NOTICE OF PROPOSED REGULATIONS

The Ministry of Labour published Notice of Intention to designate substances to which the exposure of a worker is prohibited, regulated, restricted, limited or controlled under The Occupational Health and Safety Act, 1978.

The Notice of Intention appeared in the issue of the Ontario Gazette, Saturday, June 28, 1980.

Notice is given of the following proposed regulations relating to the designations of:

Asbestos
Lead
Mercury
Noise
Isocyanates
Silica, and
Vinyl Chloride

Attention is called to the provisions of section 22(b) of The Occupational Health and Safety Act, 1978, providing that the regulations may be filed with the Registrar of Regulations sixty days after the publication of the proposed regulations in the Ontario Gazette.

Comments on the proposed regulations or any particular sections therein may be addressed to:

Designated Substances Project,
Standards and Programs Branch,
Ministry of Labour
400 University Avenue
Toronto, Ontario
M7A 1T7

Comments received may be made available for public examination.

Robert G. Elgie, M.D.
Minister of Labour

PROPOSED REGULATION UNDER
THE OCCUPATIONAL HEALTH AND SAFETY ACT, 1978

NOISE - DESIGNATED SUBSTANCE

1. In this Regulation,

   (a) "decibels A-weighted" means a unit of measurement of root-mean-square sound pressure corrected to the A-weighted scale as defined in Canadian Standards Association Standard Z107.1-1973, and "dBA" has a corresponding meaning;

   (b) "impulse or impact noise" means a sound level with a rise time of not more than 35 milliseconds to peak sound pressure level and a duration of not more than 500 milliseconds to the time when the sound level decays 20 decibels below the peak;

   (c) "peak sound pressure level" means the peak instantaneous pressure expressed in decibels using a reference pressure of 20 micropascals measured on a sound level meter with a peak hold capability or accessory the specifications of which meet or exceed those described in International Electrotechnical Commission Publication 179A, 1973;

   (d) "sound level or noise level" means an A-weighted sound pressure level measured on slow response with a sound level meter the specifications of which meet or exceed those of a Type 2 meter as described in Canadian Standards Association Standard Z107.1-1973.

2. Noise is prescribed as a designated substance.

3. This regulation applies to every employer at a work place where a worker is likely to be exposed to noise exceeding the exposures prescribed by section 4.

4. (1) Subject to section 10 every employer shall, otherwise than by requiring a worker to wear and use personal hearing protection, control the exposure of a worker to noise so that the exposure of the worker thereto does not exceed the dBA level set forth in Column 1 of the following table for the period of exposure set out opposite thereto in Column 2:

Column 1 Sound Level dBA	Column 2 Maximum Periods in Hours per Day
80	16
85	8
90	4
95	2
100	1
105	½
110	¼
115	1/8
greater than 115	0

(2) Subject to section 10, every employer shall, otherwise than by requiring a worker to wear and use personal hearing protection, control the exposure of a worker to impulse or impact noise so that the exposure of the worker thereto does not exceed the peak sound pressure level set forth in Column 1 of the following table for the maximum number of times set out opposite thereto in Column 2:

Column 1 Peak Sound Pressure Level dB	Column 2 Maximum Number of Impulses per day
120	10,000
130	1,000
140	100
greater than 140	0

(3) Notwithstanding subsection 1 and subject to section 10, where noise exposures of a worker consist of two or more periods of exposure at different noise levels every employer shall, otherwise than by requiring a worker to wear and use personal hearing protection, control the daily exposure of the worker to noise so that the daily noise exposure does not exceed unity.

(4) For the purposes of subsection 3, the daily exposure of a worker to noise shall be determined by dividing the periods of exposure of each sound level greater than 80 dBA to which a worker is exposed by the maximum time in hours that the exposure to each such sound level is limited in Column 2 of the table in subsection 1, and by adding the results of each such division together in accordance with the following formula:

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots \frac{C_n}{T_n} = \text{daily noise exposure}$$

where C is the total period of time of exposure to a sound level greater than 80 dBA and T is the maximum duration in hours per day for that sound level.

5. (1) Every employer shall cause an assessment to be made of the exposure or likelihood of exposure of a worker to noise.

(2) In causing the assessment to be made, the employer shall consider and take into account such matters as,

(a) the noise levels to which a worker is or may be exposed and their durations; and

(b) the measures and procedures necessary to control such exposure.

(3) In causing the assessment to be made, the employer shall consult thereon with the joint health and safety committee required to be established under clause b of subsection 2 of section 8 of the Act and the committee may make recommendations with respect to the assessment.

6. (1) Where the assessment discloses that a worker is likely to be exposed to noise in excess of the exposures prescribed by section 4, an employer shall develop, establish, put into effect and maintain measures and procedures to control the exposure of the worker to noise.

(2) The measures and procedures mentioned in subsection 1 shall be incorporated into a noise control program.

(3) The noise control program shall include provisions for,

(a) engineering controls and work practices to control the exposure of a worker to noise;

(b) methods and procedures to monitor the noise in the work place and the exposure of the worker thereto;

(c) personal exposure records of a worker to noise to be maintained by the employer;

(d) audiometric examinations and tests of a worker including pre-placement and periodic audiometric examinations and tests, and

(e) records of audiometric examinations and tests of a worker to be maintained by a physician who has examined the worker or caused the tests to be performed.

(4) In developing the noise control program, the employer shall consult with the joint health and safety committee and the committee may make recommendations with respect to the program.

7. Where a change is made in a process, or in the methods and procedures being used at a work place and the change might result in a significant difference in the exposure of a worker to noise, the employer shall cause a further assessment to be made forthwith and develop, establish, put into effect and maintain a noise control program to control the exposure of the worker to noise as a result of the change and the provisions of sections 5 and 6 apply.

8. Where disputes arise between an employer and a joint health and safety committee as to an assessment required under section 5 or 7 or the noise control program required under section 6 or 7 or any provisions therein, the employer or a member of the joint health and safety committee may notify an inspector thereof who shall investigate and give a decision thereon in writing to the employer and the joint health and safety committee.

9. A copy of the noise control program shall be given by the employer to each member of the joint health and safety committee and shall be made available by the employer to every worker affected thereby.

10. (1) Personal hearing protection shall not be provided by an employer to be used by a worker except where an employer establishes to the satisfaction of an inspector that,

(a) the control of the exposure of a worker to noise as prescribed by section 4 is not feasible because the measures and procedures required to do so,

(i) do not exist or are unavailable, or

(ii) are unreasonable for the length of time of exposure or the nature of the work, or

(b) the control of the exposure of a worker to noise prescribed by section 4 is ineffective because of a temporary breakdown of equipment.

(2) Where personal hearing protection is provided by an employer and used by a worker the protection shall be appropriate in the circumstances for the type and the sound levels of noise to which a worker is exposed and shall meet or exceed the requirements set out in Canadian Standards Association Standard Z94.2-1974.

(3) The employer shall provide training and instruction to a worker in the proper care and use of personal hearing protection.

11. The medical examinations and audiometric tests in a noise control program shall be under the supervision of a physician and shall provide for,

(a) a pre-placement audiometric examination including,

(i) a medical history,

(ii) a physical examination, and

(iii) audiometric tests as required by the examining physician;

(b) an annual or other periodic medical examination and audiometric tests consisting of the items prescribed by clause a.

12. (1) Where the hearing of a worker has been impaired by exposure to noise or the result of an audiometric examination of a worker discloses a threshold measurement in either ear averaging 25 dBA or more at 500, 1,000, 2,000 and 3,000 Hz, or a shift from the most recent audiogram of 10 decibels at any frequency in either ear, the physician who has examined the worker or performed or caused the tests of the worker to be performed shall forthwith report in writing his findings and recommendations to the worker, the employer, the Chief Physician, Occupational Health Medical Service of the Ministry, and with the consent of the worker, to his physician, if any.

(2) Upon the request of a worker or his authorized agent, reports of the results of medical examinations or tests shall be provided forthwith to the worker or his agent.

13. (1) The employer shall provide a copy of the personal exposure record of a worker to noise to the physician who examines the worker or performs or causes the tests of the worker to be performed.

(2) The records of medical examinations and audiometric tests of a worker by the physician who has examined the worker or performed or caused the tests of the worker to be performed and the personal exposure records of the worker shall be kept in a secure place by the physician and the employer, as the case may be, for,

(a) a period of forty years from the time such records were first made; or

(b) a period of twenty years from the time the last of such records were made,

whichever is the longer.

(3) Where the physician or the employer, as the case may be, is no longer able or willing to keep the records, the records shall be forwarded to the Chief Physician, Occupational Health Medical Service of the Ministry, or a physician designated by the Chief Physician who shall keep them in a secure place.

(4) The results of medical examinations and tests and the personal exposure records of a worker shall be made available to the worker or his authorized agent.

14. Subject to section 17, the procedure for determining the noise at a work place or to which a worker may be exposed shall be the procedure set out in the Code for Determining Noise Levels dated the 15th day of August, 1980 and issued by the Ministry.

15. The results of noise monitoring in the work place under the noise control program shall be,

(a) posted forthwith by the employer as soon as the results are available in a conspicuous place or places at the work place where they are most likely to come to the attention of the workers for a period of at least fourteen days;

(b) furnished to the joint health and safety committee; and

(c) kept for a period of at least five years.

16. The personal exposure records of a worker to be maintained under the noise control program shall identify the worker, including his date of birth and the maiden surname of his mother, his jobs or occupations at the work place, the work operations performed by him during his employment, the results of monitoring for his exposure to noise, his exposures to noise and the dates and length of time the worker used personal hearing protection equipment and its type.

17. For the purposes of this Regulation the methods and procedures that may be used or adopted to determine the noise levels at a work place or to which a worker may be exposed may vary from the Code issued by the Ministry if the factors of accuracy and precision used or adopted are equal to or exceed the factors of accuracy and precision in the Code issued by the Ministry.

18. Section 144 of Ontario Regulation 658/79 is revoked.

19. (1) This Regulation, except sections 4, 6, 7, 9 to 11 and 13 to 18 comes into force on the day this regulation is filed.

(2) Sections 4, 6, 7, 9 to 11, and 13 to 18 come into force ninety days after the day this Regulation is filed.

CODE FOR DETERMINING NOISE LEVELS

1. Sound Monitoring Instruments

A wide range of instrumentation is available for noise monitoring. The three instruments suitable for monitoring noise levels in the work place are described briefly below:

(1) A Type 2 sound level meter (SLM), as described in the Canadian Standards Association Standard Z107.1-1973, should be used to determine work area noise levels. For continuous noise, the meter should be set to the A-weighting, slow response scale. To measure impact or impulsive noise, modifications of the procedure and instrumentation for measurement of continuous noise as described in Appendix B of the Canadian Standards Association Standard Z107.2-1973, or in Publication 179A-1973 of the International Electrotechnical Commission, is necessary.

(2) Octave Band Analyzers can be used with a tape recorder to determine the frequency characteristics of a noise and possibly to determine its source as many sources produce noise with a characteristic frequency. The results of such measurements can be used to determine the type of engineering controls which would be most useful for reducing specific noise levels. Octave band filter sets described in the Canadian Standards Association Standard Z107.5-1975 are suitable.

(3) Noise dosimeters or noise exposure monitors are used to measure worker noise exposure when a worker moves to several locations during the course of a shift. The noise dosimeter measures "daily noise dose" or "daily equivalent continuous sound level exposures" of a worker. When workers are exposed to intermittent noise or variable noise levels at one site or when personal exposure monitoring is necessary, noise dosimeters are suitable.

2. Effects of the Environment on the Instrument Readings

(1) Sound measurement equipment should be designed to perform within specifications at ambient temperatures between -29°C and +60°C. Special microphones may tolerate temperature extremes: manufacturers' specifications should be consulted.

(2) Sound measuring equipment should not be stored outdoors, or in automobiles in extreme temperatures. Warm-up drift, moisture condensation on the microphone and weakened batteries may result with adverse effects on performance.

(3) Noise instruments should perform accurately unless moisture condenses or deposits on the microphone diaphragm.

(4) If prolonged sampling is required in corrosive atmospheres, the microphone should be protected by a wind screen.

(5) Atmospheric pressure and temperature may affect sound level measurements. Generally, if the altitude is less than 3,000 m the correction is negligible.

(6) Air flow across a microphone can produce turbulence and noise capable of causing error in the measurement. A wind screen should be used for all outdoor measurements and where there is significant air movement indoors (e.g. cooling or ventilation fans, gusting wind through open windows).

(7) Certain equipment such as heat sealers, induction furnaces, generators, transformers, electromagnets, arc welders and radio transmitting devices generate electromagnetic fields which, by inducing current in the electronic circuit of SLMs and dosimeters, may cause high readings. Whether this is significant may be determined by, for example, using the SLM with dummy microphone; refer to the manufacturer's instructions.

3. **Effects of Sound on the Instrument Reading**

(1) For SLMs and dosimeters using nondirectional microphones, the effects of microphone placement and orientation are negligible in a reverberant environment. If the measurement site is nonreverberant and/or the noise source is highly directional, the manufaturer's literature should be consulted to determine proper microphone placement.

(2) In evaluating impulsive noise, the crest factor for the noise to be measured should be obtained. If this is equal to or less than the measuring instrument's crest factor, the readings should be valid.

4. **Noise Monitoring Practices**

Noise monitoring requires a variety of noise measurements; consideration of the machinery involved and its immediate surroundings; an evaluation of existing hearing protection, existing and feasible engineering controls.

Noise levels within work areas and individual worker exposure to noise should both be considered.

5. **Area Noise Monitoring**

(1) Area noise monitoring is conducted to determine which areas have excessive noise levels and where noise reduction controls should be implemented. Area monitoring should include:

(a) Measurements in areas with the highest noise levels.

(b) Measurements at operator's stations and those sites where workers are most likely to be during their shift.

(c) Several measurements throughout a shift; more will be necessary in the case of fluctuating noise than steady noise.

(d) Measurements of the regularly occurring maximum and minimum noise levels.

(e) Measurements of noise produced by specific equipment in order to evaluate noise output under varying load conditions.

(2) In the case of changing work sites such as in construction, exposure levels should be estimated but should be based upon the measurement of noise output of the equipment being used.

(3) Performing Area Noise Measurements

(a) Calibration of noise measuring instruments should be performed daily, both before and after use.

(b) Calibration and measurement data should be recorded.

(c) SLM readings in a nonreverberant environment are taken by holding the SLM at arm's length with the microphone diaphragm perpendicular to the noise source. Generally this should be done for all SLM noise measurements.

(d) The body of the instrument operator should not be between the noise source and the microphone.

(e) The microphone should be in the worker's hearing zone; within 0.5 m of the head.

(f) When noise levels for the worker's two ears are different, both levels should be recorded;

(g) SLM readings are collected on the dBA slow mode for compliance purposes; dBC readings may be useful for the evaluation of hearing protection and the feasibility of implementing engineering controls.

(h) Where both continuous and impulsive noise are present, the background should be measured on the dBA fast mode to determine if the continuous noise is above the levels permitted.

6. Personal Exposure Monitoring

(1) Personal noise exposure monitoring is the most appropriate method of measuring noise in changing work places such as in the construction, mining and lumbering industries where area measurements have limited application. Personal exposure monitoring can be used in work places to determine which workers are exposed to noise in excess of levels specified by the noise regulation and therefore require personal protective equipment until control measures are completed. This type of monitoring is also practical for work areas in which workers are exposed to intermittent and variable noise levels. All data produced from personal exposure monitoring should be recorded and maintained.

(2) Performing Personal Noise Exposure Measurements

(a) Monitor workers in high noise areas. Where possible, those employees with the highest probable exposure in each job classification.

(b) Inform the worker that the dosimeter should not interfere with normal work, emphasizing that the worker should continue to work in a routine manner.

(c) Explain to each worker the purpose of the dosimeter.

(d) Instruct the worker not to remove the dosimeter unless absolutely necessary and not to cover the microphone. Inform the worker when and where the dosimeter will be removed.

(e) When the dosimeter is positioned (normally in the shirt pocket or at the waist), clip the microphone to the worker's shirt collar at the top of the shoulder. Care should be taken to ensure that the microphone is in a vertical direction, pointing upward.

(f) Position and secure any excess microphone cable to avoid snagging or inconvenience to the employee.

(g) Check the dosimeter periodically to ensure that the microphone is oriented properly.

(h) SLM readings shall be taken and noted during the different phases of work performed by the worker during the shift.

(i) Record the information.

In most work places a combination of both area and personal exposure monitoring provides the most complete information with which to assess a noise problem. For example, area monitoring at a work site is used to determine if excessive noise exists, to identify the sources, and as a guide to the control measures needed. As personal exposures of workers will differ according to their jobs, personal exposure monitoring will more precisely determine each individual's exposure.

7. Records

Comprehensive records of the monitoring should be maintained including information such as: date, time, measurement location, person conducting measurements, type and serial number of any meter used, and calibration procedures used.

APPENDIX C

THE 1978 DRAFT REGULATIONS

AUGUST 19TH, 1978

MINISTRY OF LABOUR

NOTICE OF INTENT TO REGULATE
ISOCYANATES, MERCURY, NOISE,
VINYL CHLORIDE MONOMER, AND
OCCUPATIONAL HEALTH HAZARDS

The Ministry of Labour intends to regulate general occupational health hazards and the exposures of employees to the substances: isocyanates, mercury, noise and vinyl chloride monomer. Interim drafts of these regulations are set out below. Comments are invited. These comments will be reviewed, together with those from external scientific experts and other Provincial Ministries. If any concerns remain to be addressed, further consultations will take place. The proposed regulations will be subsequently published in THE ONTARIO GAZETTE.

An impact study on the economic effects of regulating hazards to occupational health and isocyanates, mercury, noise and vinyl chloride monomer, is being developed. Any comments on this subject should be included separately from your comments on the interim draft regulations.

The following questions could be considered in preparing your comments:

Regulations Respecting Occupational Health Hazards

1) Will the scheme of progressive control measures described in section 4 adequately control, limit, or reduce an exposure?

2) Are the medical examination program, the personal exposure record program, and the health record program sufficiently comprehensive?

3) Do you agree with the process described in section 7 to establish a monitoring program?

Regulations Respecting Hazardous Substances

4) Do you agree with the exposure limits for the substance?

5) Do you agree with the respiratory equipment requirements?

6) Do you agree with the requirements for cleanliness in the workplace?

7) Do you agree that the warning notice to be posted is adequate?

8) Do you agree with the medical examination requirements?

Comments should be submitted within 60 days of the date of the publication of this notice to:

Dr. C.R. May
Assistant Deputy Minister
Occupational Health and Safety Division
Ministry of Labour
400 University Avenue
14th Floor
Toronto, Ontario
M7A 1T7

BETTE STEPHENSON, M.D.
Minister of Labour

REGULATION RESPECTING OCCUPATIONAL HEALTH HAZARDS

1. (1) In this regulation and a regulation respecting a regulated substance,

(a) "administrative controls" mean controlling, limiting or reducing the period of time of exposure to a regulated or a toxic substance or a physical agent;

(b) "ceiling exposure limit" means the maximum exposure to an airborne concentration of a regulated or a toxic substance or a physical agent that is not to be exceeded for an instant;

(c) "engineering controls" mean controlling, limiting or reducing the exposure to a regulated or a toxic substance or a physical agent by ventilation, isolation, enclosure and design of the work place, plant and equipment or one or more of such means;

(d) "physical agent" means heat, humidity, light, noise, laser, microwave energy, ultraviolet or ionizing radiation, exposure to which is limited or prescribed under a regulation, or a limit for exposure thereto is adopted as a criteria or guide under this regulation;

(e) "regulated substance" means a toxic substance the exposure to which is limited or prescribed under a regulation;

(f) "short-term exposure limit" means the maximum exposure to an airborne concentration of a regulated or a toxic substance or a physical agent in a period not exceeding fifteen minutes provided that such maximum exposure does not occur more than four times in a day at intervals of not less than sixty minutes and further provided that the time-weighted average exposure limit is not exceeded;

(g) "time-weighted average exposure limit" means the maximum average exposure in a 40 hour work week to an airborne concentration of a regulated or a toxic substance or a physical agent determined as prescribed by section 2;

(h) "toxic substance" means a biological or chemical substance, a mixture or combination of such substances in respect of which a limit for exposure thereto is adopted as a criteria or guide under this regulation;

(i) "work practices" mean controlling, limiting, or reducing exposure to a regulated or a toxic substance or a physical agent by,

(i) providing,

1. double locker rooms and showers;
2. for the laundering and cleaning of work clothing;
3. separate eating facilities;
4. washing facilities;

(ii) maintaining proper housekeeping procedures,

(iii) training workers in the handling, use and disposal of a regulated or a toxic substance, and

(iv) taking proper measures and procedures to control, limit or reduce such exposure.

(2) In a regulation made under the Act, the term,

(a) milligrams per cubic metre of air;

(b) micrograms per cubic metre of air;

(c) parts per million by volume in air;

(d) parts per billion by volume in air; and

(e) fibres per cubic centimetre of air

may be expressed respectively as,

(a) mg/m^3;

(b) $\mu g/m^3$;

(c) ppm;

(d) ppb; and

(e) fibres/cc.

2. (1) In determining the time-weighted average concentration of a regulated or toxic substance in the air in a work place and the exposure thereto,

(a) the results of the analysis of individual samples of air taken during work operations calculated in mg/m^3, ppm, ppb and fibres/cc shall be multiplied by the time in hours per day or work shift during which it is estimated that exposure to the concentration of the regulated or toxic substance obtained in the samples has occured in the work operations;

(b) the sum of the products obtained under clause (a) shall be multiplied by the number of days worked by the worker in a work week; and

(c) the result obtained under clause (b) shall be divided by 40.

(2) Where the length of exposure exceeds or is less than the length of exposure in a normal 8 hour work day and a 40 hour work week, the calculations made pursuant to subsection 1 shall be adjusted so that the result obtained will be representative of an exposure for a normal 8 hour work day and a 40 hour work week.

3. Subject to a regulation made in respect of a regulated substance, the time-weighted average exposure limits, the short-term exposure limits and the ceiling exposure limits for exposures to airborne concentrations of a biological or chemical substance or a physical agent or a mixture or combination of biological or chemical substances, set out in the booklet entitled Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1977 published by the American Conference of Governmental Industrial Hygenists are adopted as criteria or guides.

4. (1) Where exposure to a concentration in air of a regulated or a toxic substance or a physical agent in excess of,

(a) a ceiling exposure limit; or

(b) a short-term exposure limit; or

(c) a time-weighted average exposure limit

occurs as prescribed by a regulation or in a criteria or guide adopted by this regulation, the excess shall be eliminated, controlled, limited or reduced to an exposure below such limit by the adoption, application, installation and institution, in progressive stages of,

(d) engineering controls;

(e) work practices; and

(f) administrative controls.

(2) Where the measures and procedures prescribed by subsection 1,

(a) do not eliminate, control, limit or reduce exposures below the limits prescribed or adopted;

(b) are not immediately practicable; or

(c) cannot be promptly adopted, applied, installed and instituted,

suitable respiratory equipment or other personal protective equipment or devices shall be provided and used for such period or periods as a Director may permit from time to time.

5. Where a regulation or order made under the Act contains any of the forms of words relating to work practices contained in Column One indicated by a letter, the regulation shall have the same effect as if it contained the form of words in Column Two set opposite thereto and indicated by the same letter:

Column 1	Column 2
(a) Double locker rooms and shower facilities shall be provided.	(a) Double locker rooms and shower facilities shall be provided, designed so that the shower facilities are between the two locker rooms and so arranged that (i) work clothes must be removed in one locker room, (ii) the shower facilities must then be entered, and used, and (iii) street clothes must be put on in the other locker room.
(b) Clean work clothes shall be provided and used.	(b) (i) Freshly laundered work clothes shall be provided and used at not greater than 5 day intervals, (ii) contaminated work clothes shall be placed in closed containers for storage until laundered or discarded, (iii) contaminated work clothes shall be, 1. laundered at the work place in a laundry where the laundry workers are protected from exposure to the contaminant; or

			2. laundered at a laundry that is informed of the nature of the contaminant and is suitably equipped to protect its workers from the contaminant; and
			3. where laundering is impracticable, disposed of with proper precautions.
(c)	Facilities shall be provided for vacuuming work clothes and shall be used.	(c)	(i) Facilities shall be provided for vacuuming work clothes when leaving the area of exposure and shall be used.
			(ii) Compressed air or compressed gas shall not be used to blow the contaminant from work clothes unless the system has been specifically designed for that purpose.
(d)	A work place shall be cleaned only by vacuuming or the use of sweeping compounds.	(d)	(i) Vacuuming or sweeping compounds only shall be used in cleaning a work place where the substance is handled, used or stored.
			(ii) Where the substance is handled by shovelling or mechanical loading or unloading, the substance shall be thoroughly wetted, where practicable.
(e)	Eating, drinking and smoking shall be prohibited.	(e)	No food, drink and tobacco shall be taken into, left, consumed or used in any room, area or place where the substance is handled, used or stored.
(f)	Washing facilities shall be provided.	(f)	Washing facilities shall be provided at a convenient place adjacent to lunchroom and toilet facilities and hands shall be thoroughly washed before eating, smoking and using the toilet facilities.

(g) Training in proper work practices shall be provided.	(g) Training shall be provided in, 1. the hazards of the substance or agent; 2. the precautions and procedures to be followed in the handling, use and storage of the substance; 3. the proper use and care of personal protective equipment; and 4. the proper use of emergency measures and procedures.
(h) Containers shall be labelled.	(h) Where a container is used for the substance, the container shall be labelled in clear legible print to identify the substance and the label shall state the precautions to be taken in the handling, use, storage and disposal of the substance.

6. (1) A regulated or a toxic substance used, manufactured or stored in a work place shall be clearly identified by its chemical composition and a record of the chemical composition shall be kept for inspection.

(2) A record shall be kept of the quantity of a regulated or a toxic substance used, manufactured or stored in a work place and be made available for inspection.

7. (1) Where a Director is of the opinion that the health of a worker is likely to be endangered by exposure to any physical agent, or a biological or chemical substance or a mixture or combination thereof, the Director may direct that a program to monitor the exposures to such agent or substance or mixture or combination thereof shall be established and maintained as may be ordered.

(2) The direction may specify the measures and procedures that shall be taken in establishing and maintaining the program including the methods and equipment to be used, the methods of analysis and the time in which the analysis is to be completed.

(3) Within 7 days of their being obtained, the final results of the analysis shall be,

(a) sent to the Director; and

(b) posted for a period of 14 calendar days in a conspicuous place in the work place in which the program is established where it is most likely to come to the attention of the workers therein.

8. (1) Where a regulation in respect of a regulated substance or a physical agent prescribes or provides that a medical examination program shall be established and maintained, the medical examination program shall consist of,

(a) a pre-placement medical examination including,

(i) a medical history,

(ii) a physical examination, and

(iii) chest X-rays (14" x 17", 356mm x 432mm), laboratory tests and other tests including analysis of urine or blood or both as are required by the examining physician;

(b) an annual or other periodic medical examination consisting of all the items prescribed by clause a or as may be directed by the Chief Occupational Medical Services, of the Ministry.

(2) Where a regulation in respect of a regulated substance or a physical agent prescribes or provides that a personal exposure record program shall be established and maintained, the personal exposure record program shall consist of,

(i) name in full of worker;

(ii) date of birth;

(iii) sex;

(iv) Social Insurance Number;

(v) occupations or job sites;

(vi) the date occupations or jobs commenced;

(vii) the date occupations or jobs ended;

(viii) the kind of operations or processes involved;

(ix) the regulated substance or physical agent to which exposure occurred;

(x) time-weighted average exposures;

(xi) short-term exposures above the time-weighted average exposures limits; and

(xii) length of exposure to concentrations during a normal work shift and during other than a normal work shift.

(3) Where a regulation in respect of a regulated substance or a physical agent prescribes or provides that a health record program shall be established and maintained, the health record program shall consist of,

(i) dates of visits to occupational health service, if any;

(ii) medical examination reports;

(iii) health assessments;

(iv) results of X-rays and laboratory tests;

(v) copies of referral to a hospital or physician, if any;

(vi) copies of Forms 7 and 8 of Workmen's Compensation Board, if any;

(vii) relevant correspondence or copies thereof concerning health; and

(viii) copies of an immunization procedure, if any.

9. (1) The Minister may by order in writing require the establishment and maintenance of an occupational health service at a work place or for a group of work places.

(2) The occupational health service shall be under the direction of a physician and shall consist of,

(i) pre-placement medical examinations;

(ii) periodic medical examinations;

(iii) X-rays and laboratory tests;

(iv) emergency care and advice for major and minor injuries and illnesses occurring at the work place;

(v) rehabilitation where required; and

(vi) first aid training.

(3) The physician having the direction of the occupational health service shall issue a certificate signed by him to an applicant for work, a worker, and to the employer giving his medical opinion,

(a) whether the applicant or worker is fit for the work he is to perform or is performing;

(b) whether the applicant or worker is fit for such work subject to specified limitations and if so the nature of such limitations, or

(c) whether the applicant or worker is unfit for the work he is to perform or is performing.

10. (1) A person or a worker undergoing a pre-placement medical examination and an annual or other periodic medical examination, shall at the time of such examination give to the examining physician a form for certification that has attached a colour photograph at least 1 5/8 inches by 1 5/8 inches (60mm x 60mm), of himself showing a full front view of the head and shoulders taken against a plain white background within the last 12 months with a 1/2 inch (15mm) signature strip at the bottom.

(2) The person or worker shall sign his signature on the signature strip on each of the copies in the presence of the examining physician who shall certify the copies on the back as a true likeness of the person.

(3) The form for certification and photograph shall be provided by the employer.

11. (1) Where an applicant for work or a worker is required to undergo any medical examination, test or X-ray, under a regulation, the applicant or the worker shall present himself therefor, undergo the same and consent to the taking of specimens of blood, sputum, urine, or other biological material as may be required.

(2) Where a Director so requires, a portion of a specimen of blood, sputum, urine or other biological material as required shall be submitted to the Occupational Health Laboratory of the Ministry or a laboratory approved by the Minister.

(3) Where a regulation or a Director so requires chest X-rays and pulmonary function tests shall be done by the Industrial Chest Disease Service or a facility approved by the Chief, Industrial Chest Disease Service of the Ministry.

(4) Any equipment used in obtaining a specimen shall be free from a regulated substance.

(5) Where an applicant or a worker so requests, a sample of a specimen of urine or blood shall be divided into two parts, one of which shall be submitted as a Director requires or a regulation prescribes and the other given to the applicant or worker in a sealed container properly identified.

(6) The costs of medical examinations and laboratory tests shall not be payable by an applicant or a worker.

12. A copy of the results of all X-rays and tests shall be forwarded by the laboratory or facility within seven days,

(a) to the Chief, Medical Service, Occupational Health Branch, of the Ministry;

(b) to a physician designated by the worker; and

(c) to a physician designated by the employer.

13. Where the report of a medical examination, the result of an X-ray or laboratory tests show that the health of a worker may have been impaired by reason of his exposure to concentrations of a regulated substance, or a physical agent,

(a) the physician performing the medical examination shall forthwith;

(i) submit a report thereof to the Chief of the Medical Service, Occupational Health Branch of the Ministry,

(ii) notify the worker and the employer with respect to the fitness of the worker to work; and

(b) the employer shall not expose the worker to such substance for a period of time as may be specified by the Chief of the Medical Service, Occupational Health Branch of the Ministry.

14. (1) A worker's personal records obtained in a medical examination program, a personal exposure record program and a health record program shall be kept in a secure place by the examining physician for,

(a) a period of forty years from the time such personal records were first made; or

(b) a period of twenty years from the time the last of such personal records were made,

whichever is the longer.

(2) Where the examining physician is no longer able to or desirous of keeping the records prescribed to be kept by subsection 1, the records shall be forwarded to the Chief of the Medical Service, Occupational Health Branch of the Ministry.

REGULATION MADE IN RESPECT OF NOISE

1. Noise is prescribed as a regulated physical agent.

2. In this regulation,

(a) "steady noise" means a noise that does not fluctuate by more than 2 decibels;

(b) "continuous exposure" means constant duration of exposure to noise during a work shift;

(c) "decibels A-weighted or dBA" means a unit of measurement of sound pressure level corrected to the A-weighted scale as defined in the Canadian Standards Association, Standard Z107.1-1973;

(d) "impulsive or impact noise" means a sound with a rise time of not more than 35 milliseconds to peak intensity and a duration of not more than 500 milliseconds to the time when the sound level decays 20 dB below the peak intensity;

(e) "intermittent noise" means a noise whose sound pressure level equals the ambient environmental level two or more times during the period of observation. The period of time during which the level of the noise remains at an essentially constant value different from that of the ambient is on the order of one second or more;

(f) "noise level" or "sound level" means a weighted sound pressure level measured by the use of a sound level meter on slow response;

(g) "peak sound pressure level" means the peak instantaneous pressure expressed in decibels using a reference level of 20 micropascals measured on a sound level meter with a peak hold capability or accessory the specifications of which meet or exceed those described in the International Electrotechnical Commission Publication 179A, 1973;

(h) "rms" means root-mean-square;

(i) "sound pressure level" means 20 times the logarithm to the base 10 of the ratio of the rms pressure of a sound to the rms of the reference pressure using a reference of 20 micropascals;

(j) "sound level meter" means a metering device having a characteristic, the specifications of which are equal to or exceed those of a Type 2 meter as described in the Canadian Standards Association Standard Z107.1-1973;

(k) "octave band analyzer" means a metering device having a characteristic, the specifications of which are equal to or exceed those of a Type 1 meter as described in the Canadian Standards Association Standard Z107.1-1973 and an octave band filter set, the specifications of which are equal to or exceed those of a Class II designation as described in the Canadian Standards Association Standard Z107.5-1975;

(1) "personal noise dose-meter or dosimeter" means a self-contained instrument for the automatic assessment of personal noise exposure,

(i) the meter characteristics which are equal to or exceed those of a Type 2 sound level meter as described in the Canadian Standards Association Standards Z107.1-1973,

(ii) an integral or separate indicator, the read-out of which shall be in percentage of allowable daily dose, and

(iii) a maximum level indicator to signify exceedance of 115 dBA as described in the Canadian Standards Association, Temporary Standard, P9.2.16.

3. The maximum duration of exposure to a sound level of noise shall be that shown in the following Table:

Maximum Duration in hours per day	Maximum Sound Level dBA
16	80
8	85
4	90
2	95
1	100
1/2	105
1/4	110
1/8	115

4. (1) The duration of intermittent exposures in a day to a sound level of steady noise shall be the cumulation of the intermittent exposures.

(2) The maximum duration of intermittent exposure to a sound level of steady noise shall be that shown in the Table immediately following Section 3.

5. (1) The duration of intermittent exposures or of continuous exposure to intermittent sound levels at or above 80 dBA shall be calculated as follows:

$$\frac{C1}{T1} + \frac{C2}{T2} + \frac{C3}{T3} + \frac{Cn}{Tn}$$

where C_1 is the total time of exposure to a particular sound level of intermittent noise and T_1 is the maximum duration in hours for that particular sound level as shown on the Table immediately following Section 3.

(2) Where the sum of the fractions exceed one, the maximum duration of intermittent exposures or of exposure to intermittent sound levels is exceeded.

6. The ceiling exposure limit to steady noise or intermittent noise is 115 dBA.

7. (1) Subject to subsection 2, exposure to impulsive or impact noise shall not exceed 140 dB peak sound pressure level.

(2) Where exposure to an impulsive or impact noise occurs more than 100 times in a working day, exposure to such noise shall not exceed,

for the number of impacts	maximum dB peak sound pressure level
1 - 100	140
101 - 1,000	130
1,001 - 10,000	120

8. (1) In a work place where exposure to noise levels is likely to exceed the maximum prescribed by this regulation a noise level monitoring program shall be established to monitor noise levels,

(a) at intervals of at least twelve months;

(b) within 60 days of any major change to or modification of existing equipment, machinery, process or methods which may affect the noise levels; and

(c) as a Director may from time to time require.

(2) Copies of the results of sound level monitoring shall within 7 days of the monitoring, be,

(a) submitted to the Director, Occupational Health Branch of the Ministry; and

(b) posted for a period of not less than 14 calendar days in a conspicuous place in the work area where they will come to the attention of the workers.

9. (1) Where the results of sound level monitoring show that the maximum durations of exposure prescribed by sections 3, 4, 5 or 6 have been exceeded, or the maximum exposure to impulse or impact noise prescribed by section 7 has been exceeded, the provisions of subsection 1 of section 4 of the Occupational Health Hazards Regulation shall apply.

(2) Hearing protection shall be provided and used under the provisions of subsection 2 of section 4 of the Occupational Health Hazards Regulation.

(3) In a work place where the health of a worker is likely to be endangered by exposure to excessive noise or where a Director so orders, a personal exposure record shall be maintained for such worker.

10. A clearly visible notice of durable material in the form immediately following this section shall be posted and kept posted at the entrances to a work place where the exposure to sound levels are likely to exceed 85 decibels.

WARNING
HIGH NOISE LEVEL AREA
HEALTH HAZARD
USE HEARING PROTECTION

11. (1) An audiometric testing program as prescribed by the Chief, Occupational Health Medical Service, shall be established and maintained for workers in a work area where the hearing of the workers is likely to be affected by noise levels.

(2) The audiometric testing program shall consist of,

(a) a pre-placement audiometric test;

(b) periodic audiometric tests to be taken,

1. biennially where the noise levels range from 80 dBA to 100 dBA;

2. annually where the noise levels exceed 100 dBA, or

3. at such times as a Director may order;

(c) an audiometric test to be taken when employment in the work place terminates, and

(d) as directed by the Chief, Occupational Health Medical Service.

(3) Audiometric tests shall,

(a) not be taken unless in the period of 16 hours preceding the test a worker has been exposed to noise levels less than 80 dBA;

(b) be given by a competent person; and

(c) be given only in a place where the maximum background sound levels do not exceed those set out in the following table:

Octave Band					
Centre Frequency (Hz)	500	1,000	2,000	4,000	8,000
Background Sound Pressure					
Level (dB)	30	30	37	47	57

(4) The audiometer used in audiometric testing shall,

(a) meet or exceed the specifications set out in the Canadian Standards Association Standards Z107.4-1975;

(b) be calibrated annually for its conformity with the tolerance specified in the Standard mentioned in clause a; and

(c) have its accuracy checked by a biological calibration at least once a month, and before a period of sustained use.

12. (1) Where an audiometric test discloses that a worker has suffered a binaural hearing loss averaging 26 decibels or over at 500, 1,000, 2,000, and 3,000 Hertz the worker shall be advised to consult a physician.

(2) Where the audiometric test of a worker discloses that there has been a shift of 15 decibels or more at 500, 1,000, 2,000 or 3,000 Hertz in a direction of increased hearing loss from his first audiogram,

(a) the worker shall be advised; and

(b) a Director shall be notified.

13. (1) The provisions of subsection 1 of section 14 of the Occupational Health Hazards Regulation, with all necessary modifications, apply to the reports of audiometric tests.

(2) A worker shall be promptly advised of the results of an audiometric test.

APPENDIX D

SUMMARY OF THE MAIN ISSUES IN THE PUBLIC RESPONSE TO THE DRAFT NOISE REGULATION

SUMMARY OF THE MAIN ISSUES IN THE PUBLIC RESPONSE TO THE DRAFT NOISE REGULATION

Sixty-three letters or briefs were submitted to the Ministry with respect to the draft regulation published in The Ontario Gazette on August 19, 1978 (See Appendix E). The letters and briefs have been analysed by the staff of the Occupational Health and Safety Division to identify the salient views and concerns raised by the various respondents. The comments received are summarized below in a manner that is designed to highlight both the common and divergent views expressed by the respondents with respect to the draft regulation and specific provisions.

In general, respondents either accepted or supported the regulation of work exposure to hazardous levels of noise.

Reduction of the Sound Exposure Limit from 90 dBA to 85 dBA

The reduction of the noise exposure limit for 8 hours of daily exposure to 85 dBA from 90 dBA was the main issue discussed in the responses.

Industry overwhelmingly preferred a 90 dBA standard, believing this limit to be adequently protective, either as a single measure or when combined with personal hearing protection and audiometry. Reducing exposure levels to 85 dBA by implementing engineering controls was considered impractical because of prohibitive costs.

Industry briefs raised a number of specific points with regard to the technical and economic feasibility of reducing noise levels to comply with the proposed standard. It was argued that high levels of noise output are inherent in the design of many machines and processes and that quieter equipment is simply beyond current technology in many cases. Imported equipment, in particular, may not be designed to satisfy the conditions of a stringent noise regulation. It was noted that attempts to remedy such situations by the use of add-on silencers and mufflers often fail to adequently reduce noise levels. Where technology is available to comply with the regulation, industry contended that compulsory implementation of engineering controls may affect an industry's ability to compete, especially with firms operating in unregulated areas.

Labour, on the other hand, took the position that a further reduction of continuous or intermittent noise levels to 80 dBA for 8 hours of exposure in a working day was required to achieve adequate worker protection. It was argued that 80 dBA should at least be used as a standard for the installation of new equipment.

Medical opinion was divided on the question of whether the reduction of noise levels from 90 dBA to 85 dBA was necessary to adequately protect the hearing of workers.

Methods of Controlling Noise Exposure

As noted above, industry representatives argued that compliance with the proposed exposure limit of 85 dBA through the implementation of engineering controls presented considerable technical and economic problems for industry in Ontario. In light of these problems, it was maintained that the use of personal hearing protection is in many cases a more realistic method of reducing noise exposure in the work place. If such an approach were adopted, it was contended that individuals particularly susceptible to noise-induced hearing damage could be adequately protected by audiometric testing programs. In general it was argued that employers should be allowed greater latitude in the selection of alternative hearing protection strategies.

Specific concern was expressed regarding the order in which administrative controls (such as the reduction of exposure time) and the use of personal hearing protection were required by the original draft. It was noted that the use of personal hearing protection would be a more effective approach to limiting exposure in many work places than the reduction of exposure time and that this latter protection technique should not necessarily precede the use of personal hearing protection in terms of the progressive implementation of controls outlined by the regulation.

Labour insisted that control of noise at the source was the only acceptable approach to limiting worker exposure, with personal hearing protection used only as a temporary measure or a last resort. Audiometric testing was seen to be a last line of defence against hearing damage rather than a central technique in controlling worker exposure to excessive noise. It was also noted that personal hearing protection often does not adequately reduce noise levels to provide sufficient protection for exposed workers.

Duration of Exposure to Continuous or Intermittent Noise Levels in Excess of 85 dBA

It was argued in a number of briefs that exposure time should be halved for each 3 dBA increase in noise levels above the standard since such a rule is more theoretically consistent than the 5 dBA rule proposed. Labour, in particular, stated its support of the 3 dBA "doubling rule".

Audiometric Testing

Industries with a high rate of employee turnover argued that audiometric testing of transient workers according to the requirements of the original draft regulation would result in massive duplication and unjustifiable costs. For example, in the constuction industry, employees change jobs an average of four times during the year and would receive, therefore, four audiograms in twelve months. It was argued that this would place a considerable burden upon the industry.

Industry questioned whether the costs of performing audiometric testing as stipulated outweighed the benefits. Specific concern was expressed regarding the costs of maintaining records of audiometric tests and individual noise exposures, as well as noise monitoring results.

Noise Monitoring

Submissions from labour groups favoured initial monitoring of noise levels in all work places. Industry, on the other hand, claimed that noise monitoring is superfluous if personal hearing protection is available and audiometric testing is provided. It was contended that monitoring would incur considerable costs if required as outlined in the original draft regulation.

Industry pointed out the difficulties in monitoring many work places where operations change frequently, such as mines, construction sites, and lumbering operations. Some respondents maintained that the monitoring requirement should be removed for this reason. Others argued that individual worker exposure should be monitored rather than entire work places because of the variations in noise levels within a work place.

Industry also criticized the monitoring interval as being too short and recommended extensions of the period between tests as well as an extension of the period allowed before reporting results to the Ministry and the workers.

Medical Referral

The proposed "action levels" or levels of hearing loss indicated by audiometric testing at which workers will be advised to consult a physician were criticized by some respondents as insufficiently protective. It was recommended that workers be advised to seek medical attention when a shift of 10 dB at any speech frequency is confirmed. The draft regulation had proposed averaging the shift over several frequencies with a 15 dB action level.

APPENDIX E

ORGANIZATIONS THAT RESPONDED TO THE PUBLICATION OF THE DRAFT REGULATION RESPECTING NOISE

ORGANIZATIONS THAT RESPONDED TO THE PUBLICATION OF THE DRAFT REGULATION RESPECTING NOISE

Agnew Lake Mines Limited
P.O. Box 91 - Commerce Court West
Toronto, Ontario
M5L 1C7

The Algoma Steel Corporation, Limited
Sault Ste. Marie
Ontario
P6A 5P2

Allied Chemical of Canada Limited
P.O. Box 2000
Amherstburg, Ontario
N9V 2Z6

American Industrial Hygiene Association
Ontario Section
P.O. Box 1232
Postal Station "Q"
Toronto, Ontario
M4T 2P4

Canada Alloy Castings Ltd.
529 Manitou Drive
Kitchener, Ontario
N2C 1S2

Canada Malting Co. Ltd.
Box 248, Terminal A
Toronto, Ontario
M5W 1B8

Canada Cement Lafarge Ltd.
240 Duncan Mill
Toronto, Ontario

The Canadian Chemical Producers' Association
Suite 505, 350 Sparks Street
Ottawa, Ontario
K1R 7S8

Canadian Diamond Drilling Association
Suite 719, 74 Victoria Street
Toronto, Ontario
M5C 2A5

Canadian Longyear Ltd.
P.O. Box 330
North Bay, Ontario
P1B 8H6

Canadian Paint Manufacturers' Association
Suite 800, 2050 Mansfield
Montreal, Quebec
H3A 1Y9

Canadian Standards Association
178 Rexdale Boulevard
Rexdale, Ontario
M9W 1R3

Canadian Urethane Manufacturers' Association
1 Yonge Street
Suite 1400
Toronto, Ontario
M5E 1J9

Canadian Water Heater Manufacturers' Association
1 Yonge Street, Suite 1400
Toronto, Ontario
M5E 1J9

Chrysler of Canada Limited
Chrysler Center
Windsor, Ontario
N9A 4H6

City of Toronto
Department of the City Clerk
City Hall
Toronto, Ontario
M5H 2N2

Construction Safety Association
74 Victoria Street
Toronto, Ontario
M5C 2A5

Crothers
1 Crothers Drive
P.O. Box 5511
Concord, Ontario
L4K 1E2

Abraham M. Crotin, M.D., F.R.C.S. (C)
Thomas J. Shoniker Building
Suite 5B2
2877 Ellesmere Road
West Hill, Ontario
M1E 4C1

Dickenson Mines Ltd.
Balmertown
Ontario

Domtar Chemicals Group
Lime Division
P.O. Box 100
Beachville, Ontario
N0J 1A0

Domtar Chemicals Group
Sifto Salt Division
Goderich Mine, Box 96
Goderich, Ontario
N7A 3Y9

Dow Chemical of Canada, Limited
South Vidal Street
P.O. Box 3030
Sarnia, Ontario
N7T 7M1

Dominion Foundries and Steel, Limited
P.O. Box 460
Hamilton, Ontario
L8N 3J5

Dubreuil Brothers Limited
Dubreuilville
Ontario

Dupont of Canada Limited
Research Centre, Research Division
Box 5000
Kingston, Ontario
K7L 5A5

Electical Utilities Safety Association of Ontario, Incorporated
Unit 1, 81 Kelfield Street
Rexdale, Ontario
M9W 5A3

Elliot Lake Mines Safety Group
45 Valley Crescent
Elliot Lake, Ontario
P5A 2G9

Ministry of the Environment
Laboratory Services Branch
Resources Road, P.O. Box 213
Rexdale, Ontario
M9W 5L1

Fiberglas Canada Ltd.
3080 Yonge Street
Toronto, Ontario
M4N 3N1

Ford Motor Company of Canada, Limited
The Canadian Road
Oakville, Ontario
L6J 5E4

Forest Products Accident Prevention Association
P.O. Box 270
North Bay, Ontario
P1B 8H2

General Motors of Canada Limited
Oshawa, Ontario

B.F. Goodrich Canada Ltd.
409 Weber West
Kitchener, Ontario
M2C 4J5

Goodyear Canada Inc.
3050 Lake Shore Boulevard West
Toronto, Ontario
M8V 1K4

Hauser, Rontal, Rontal and Jacob
21700 Northwestern Highway
Tower 14, Suite 545
Southfield, Michigan 48075
U.S.A.

Imperial Oil Limited
1 Duncan Mill Road
Don Mills, Ontario
M3B 1Z2

Inco Limited
1 First Canadian Place
Toronto, Ontario
M5X 1C4

Inco Metals Company
Copper Cliff, Ontario
P0M 1N0

Industrial Accident Prevention Association
2 Bloor Street East, 23rd Floor
Toronto, Ontario
M4W 3C2

Industrial Truck Association of Canada
One Yonge Street
Suite 1400
Toronto, Ontario
M5E 1J9

Kelsey-Hayes Canada Limited
Woodstock Division
P.O. Box 300
Woodstock, Ontario

Lake Ontario Cement Limited
P.O. Box 620
Picton, Ontario
K0K 2T0

Mines Accident Prevention Association of Ontario
199 Bay Street
Toronto, Ontario
M5J 1L4

Mount Sinai Hospital
Department of Otolaryngology
600 University Avenue
Toronto, Ontario
M5G 1X5

Municipal Engineers Association
P.O. Box 520
St. Thomas, Ontario
N5P 3V7

Ministry of Natural Resources
Box 1168
Chatham, Ontario
N7M 5L8

Occupational Health Resource Centre
Health Sciences
Queen's University
25 Union Street
Kingston, Ontario
K7L 2N6

Ontario Federation of Labour
15 Gervais Drive
Don Mills, Ontario
M3C 1Y8

Ontario Hydro
700 University Avenue
Toronto, Ontario
M5G 1X6

Ontario Occupational Health Nurses Association
3209 Rymal Road
Mississauga, Ontario
L4Y 3B8

Ontario Hospital Association
150 Ferrand Drive
Don Mills, Ontario
M3C 1H6

Ontario Mine Contractors Safety Group
45 Valley Crescent
Elliot Lake, Ontario
P5A 2G9

Ontario Mining Association
10th Floor, 199 Bay Street
Toronto, Ontario
M5J 1L4

H.E. Pearsall, M.D., F.A.C.S., F.R.C.S. (C)
Suite 204
845 Regent Street South
Sudbury, Ontario
P3E 4T3

Phillips Cables Ltd.
King Street West
Brockville, Ontario
K6V 5W4

Rubber Association of Canada
100 University Avenue
Toronto, Ontario
M5J 1V6

SNC/GECO Canada Inc.
74 Victoria Street
Toronto, Ontario
M5C 2A5

Society of the Plastics Industry of Canada
Suite 104
1262 Don Mills Road
Don Mills, Ontario
M3B 2W7

The Steel Company of Canada, Limited
General Office
Stelco Tower
Hamilton, Ontario
L8N 3T1

Union Carbide Canada Limited
123 Eglinton Avenue East
Toronto, Ontario
M4P 1J3

University of Toronto
Faculty of Medicine
Department of Preventive Medicine and Biostatistics
Toronto, Ontario
M5S 1A8

Workmen's Compensation Board
2 Bloor Street East
Toronto, Ontario
M4W 3C3

APPENDIX F

HEALTH EFFECTS OF NOISE
PREPARED BY
SPECIAL STUDIES AND SERVICES BRANCH

BACKGROUND DOCUMENT ON NOISE

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Health Studies Service

March 1, 1979

INTRODUCTION

Noise has long been recognized as a hazard to human hearing, and some occupations are notorious for their deleterious effects on workers' hearing, as witnessed, for example, by the expression 'boiler-maker's ear'.[1] Since the Second World War, much effort has been expended in establishing the relationship between noise exposure and hearing loss, and much has been learned. Although, much remains to be discovered, it is possible to propose occupational standards for both steady-state and impact noises based upon realistic damage - risk criteria.

It has recently come to be realized that apart from its effects upon hearing, noise can influence a number of other bodily functions via the nervous and hormonal systems. Jonsson and Hansson,[2] in a preliminary study of Swedish auto-workers, showed mean blood pressures to be higher in a group of workers with noise-induced hearing loss than in a group with normal audiograms. They also showed a higher prevalence of hypertensives in the noise-injured group. They postulate that prolonged exposure to a stressful stimulus may cause repeated rises in blood pressure leading to circulatory adaptations and a permanent rise in blood pressure.

The major concern about non-auditory health effects from noise arises from the ability of noise under some circumstances to act as a general non-specific biological stressor. The effects of noise, if any, are thus likely to be distributed over a large number of common cardiovascular and other maladies whose causation is complex, and attributable to other factors as well, making any statement about cause and effect difficult.[3] There are also a number of psychological effects in the workplace attributable to noise which have received study by industrial psychologists. These include annoyance effects, effects on work performance, absenteeism, and injury rates.[3]

With the exception of hearing loss, none of the effects of noise on man have been sufficiently well documented to permit a quantitative standard incorporating a damage-risk estimate to be formulated. Although it is recognized that these other phenomena may be important as regards a worker's health, it is a universal practice to consider only the effects of noise on hearing in proposing legislative standards. As

further data becomes available, it may well be possible to take account of these other phenomena in a more generalized formulation. Our attention in this document will be focussed solely upon the relationships between noise and hearing.

SOUND AND NOISE

Sound is an oscillation in air pressure, or, in particle position in an elastic medium. These oscillations are converted to electrical signals by the ear and perceived as a sensory experience by the brain. Noise may be loosely defined as unwanted sound.

Sound waves may be characterized by their frequency in cycles per second, or Hertz (Hz), and by their amplitude. A complex sound or noise may be described in terms of the amount of energy present at discrete frequencies or in frequency bands.

The human ear is capable of hearing sound over an enormous range of pressures, from 20 micropascals (Newtons/m^2) to 200 Pascals, a factor of 10 million. The intensity of sound is proportional to the square of the pressure fluctuation i.e.

$$I \propto p^2$$

It has been determined that the ear responds logarithmically to an acoustical stimulus and this response is described on the decibel (dB) scale. Thus, intensity:

$$I\,(dB) = 10 \log_{10} (I/I_{ref}) = 10 \log_{10} (p^2/p^2_{ref}) = 20 \log_{10} (p/p_{ref})$$

By convention, the reference level of pressure has been chosen at the threshold of hearing of young, healthy ears; that is 20, micropascals. Because decibels are logarithmic units, they cannot be added or subtracted arithmetically. Thus, if the intensity of a sound is doubled, there is a corresponding increase of only 3 dB, not double the number. For example, if one machine produces a sound of 90 dB, and a second identical machine is placed adjacent to the first, the combined sound intensity would be 93 dB, not 180 dB. On the dB scale, zero is the threshold of hearing and 130 dB is the threshold of pain.

Typical values of sound levels are given in Figure 1.

Figure 1. A-weighted sound levels from familiar sources.

AT A GIVEN DISTANCE FROM NOISE SOURCE	DECIBELS RE 20 µPa	ENVIRONMENTAL
	140	
50 mp SIREN (106')		
	130	
JET TAKEOFF (200')		
	120	
RIVETING MACHINE	110	CASTING SHAKEOUT AREA
CUT-OFF SAW PNEUMATIC PEEN HAMMER	100	ELECTRIC FURNACE AREA
TEXTILE WEAVING PLANT SUBWAY TRAIN (20')	90	BOILER ROOM PRINTING PRESS PLANT
PNEUMATIC DRILL (50')	80	TABULATING ROOM INSIDE SPORT CAR (50 mph)
FREIGHT TRAIN (100') VACUUM CLEANER (10') SPEECH (1')	70	NEAR FREEWAY (AUTO TRAFFIC)
	60	LARGE STORE ACCOUNTING OFFICE
LARGE TRANSFORMER (200')	50	PRIVATE BUSINESS LIGHT TRAFFIC (100') AVERAGE RESIDENCE
	40	MIN LEVELS RESIDENTIAL AREAS IN CHICAGO AT NIGHT
SOFT WHISPER (5')	30	STUDIO (SPEECH)
	20	STUDIO FOR SOUND PICTURES
THRESHOLD OF HEARING YOUTHS	0	

A noise pattern may be described as continuous, impulsive (impact), or a mixture of these two. A continuous noise is continuously present and may be steady or varying more or less rapidly in time. Most human studies involve continuous exposures in steady noise fields. Impulsive or impact noises are of an almost infinite variety, and are described by such parameters as rise time, duration, decay time and peak sound pressure level. Information about the effects of this kind of noise on human hearing is scanty.

THE MEASUREMENT OF NOISE

Noise is commonly measured with commercially available sound level meters conforming to national standards. These devices have several available scales which introduce filter networks to influence their response characteristics. As illustrated in Figure 2, the normal human ear has maximum acuity around 1 kHz, with acuity falling off at both high and low ends of the frequency range. The A-scale of the sound level meter has been designed to reproduce this response. Epidemiological studies have shown good correlation between noise levels on this scale and noise - induced hearing effects, and so for this reason, and because of its ease of use, this scale has been widely adopted in the specification of noise standards. These instruments also have networks which permit a fast or a slow response characteristic. In the measurement of industrial noise, the slow response scale is used.

Figure 3 illustrates the response characteristics of these meters.

Impact noise is a more difficult noise to measure because of the rapid pressure changes involved and their complicated time behaviour. A simple, but very rough approach, is to make use of a meter with a peak-hold capacity and to count the number of impacts. More sophisticated systems use a microphone with an oscillographic display to determine the decay time of the impacts as well as the peak heights. The ideal system, which is undergoing development in Europe, is the use of integrators or dosimeters which measure the total acoustic energy received during a given period of time.

Figure 2
The Response of the Ear to Sound

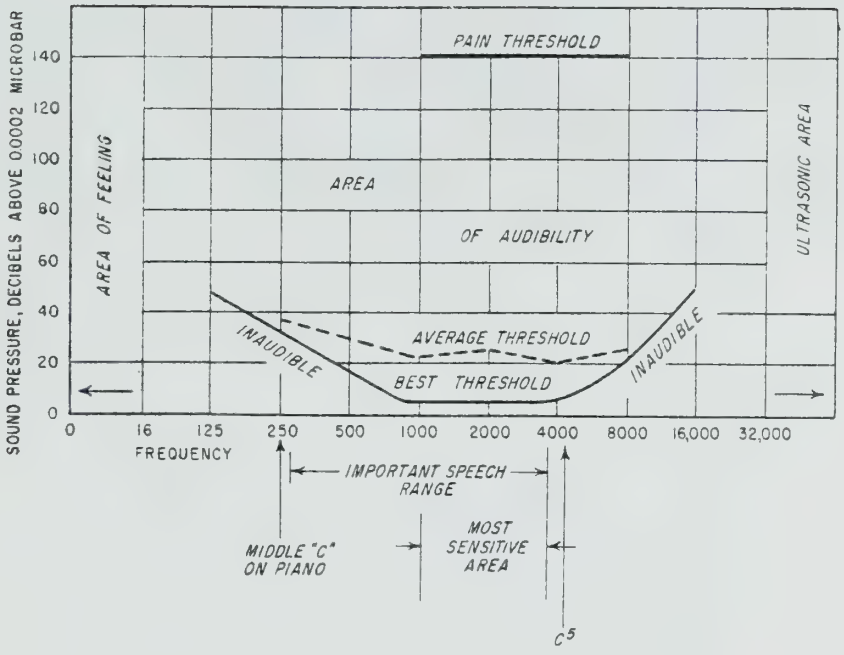
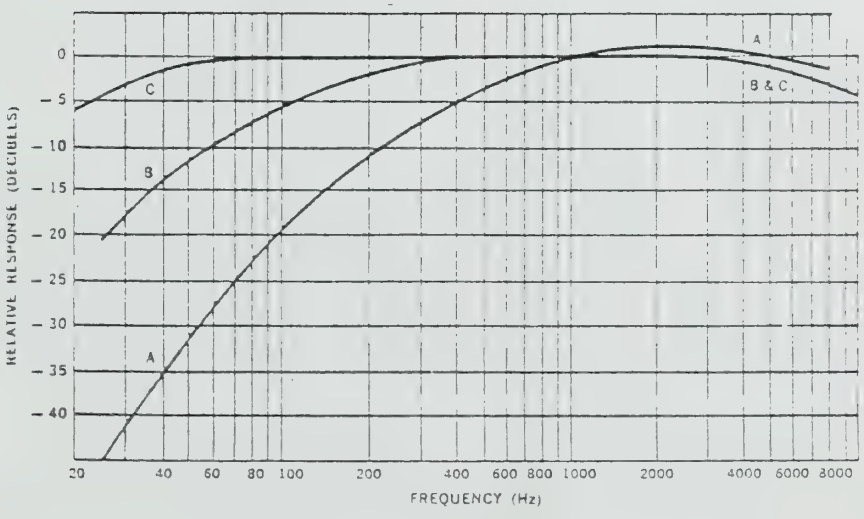


Figure 3



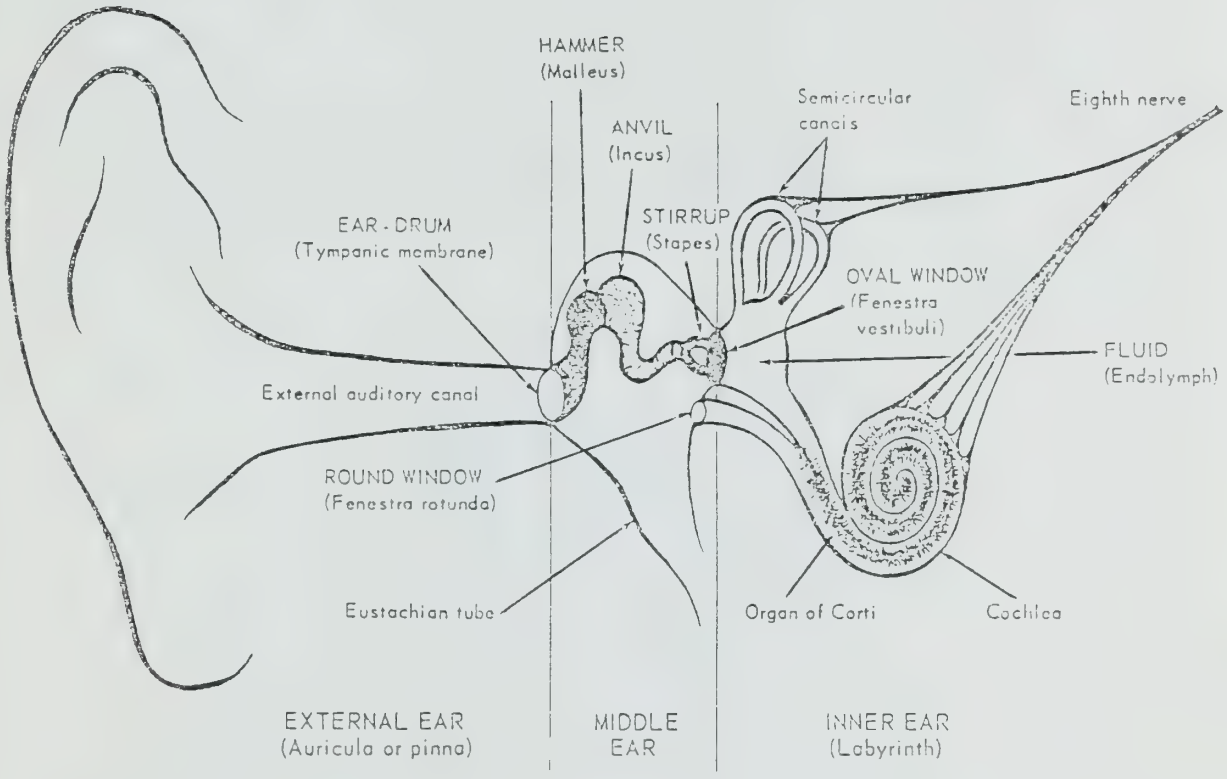
Frequency-response characteristics of a sound level meter with A-, B-, and C-weighting.

NORMAL HEARING AND ITS MEASUREMENT

The young human ear is capable of hearing sound in the frequency range 16-20,000 Hz with a threshold sound pressure level of 20 micropascals. The anatomical basis of the hearing mechanism is illustrated in Figure 4, in which the ear is divided schematically into three parts; the external ear, which conducts air pressure fluctuations to the ear drum, the middle ear, which acts as a transducer to convert pressure variations into mechanical motion, and the inner ear, housed in bone, which converts this mechanical motion into electrical energy for transmission to the brain. The organ of Corti, housed in the cochlea, is the site at which noise damages the ear, causing the death and loss of cells from this organ.

Figure 4

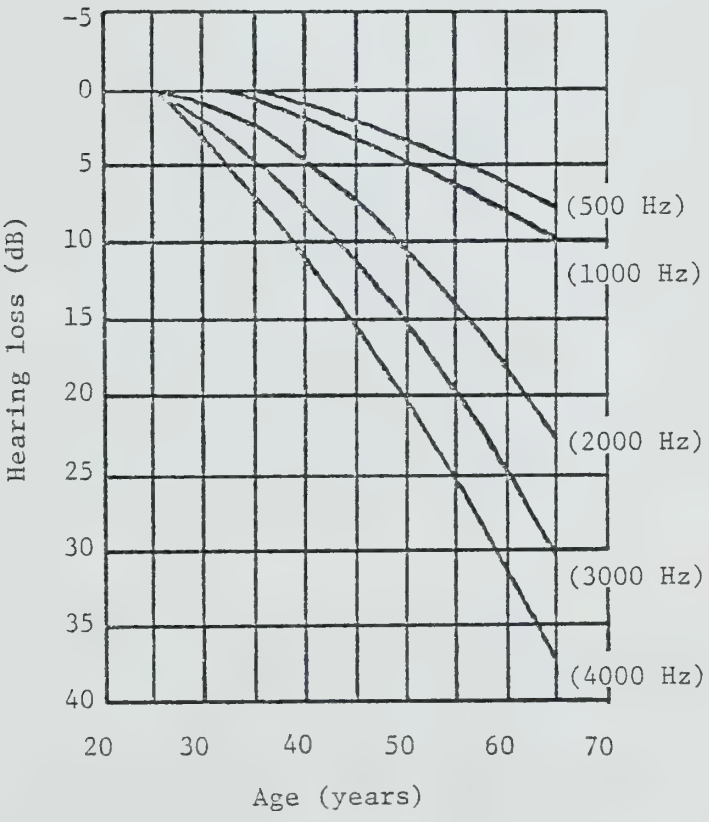
Schematic Diagram of the Ear



The healthy ear is not equally sensitive to sound of all frequencies, being most acute in the range encompassing the speech frequencies, and this is illustrated in Figure 2. Hearing acuity is lost progressively with age, a phenomenon known as presbycusis, and this is illustrated in Figure 5. The highest frequencies are affected the earliest and most severely.

Figure 5

PRESBYCUSIS CURVES FOR MEN:
AVERAGE HEARING LOSS TO BE EXPECTED WITH AGE



Hearing level is measured by a technique known as pure-tone audiometry in which sinusoidal tones of calibrated intensity are presented to the subject via earphones and the threshold of audibility is noted for each ear. Testing is usually done at standard frequencies in the range 500-8,000 Hz, and threshold values are expressed in dB relative to an accepted standard. Most testing is done in 5 dB steps. The test must be done in a sufficiently quiet environment to avoid masking of the audiometric tones by other sounds.

a) Quantitative Aspects:

The first problem to be resolved is that of the determination of "normal" hearing. On the basis of American work, an American standard for normal hearing was published (ANSI, 1951), but this has increasingly come to be regarded as an under-estimate of the sensitivity of young normal ears. The thresholds expressed in the original British standard (BSI, 1954) regarded as normal for young people were, on average, 10 dB lower than the American. An international standard (ISO, 1964) which is quantitatively similar to the British standard is now in use. The ISO recommendations (R389) are in the form of threshold values of sound pressure level to be taken as representative of the modal values for the thresholds of hearing of persons 18-30 years of age, in a normal state of health, and free from all signs or symptons of ear disease and from wax in the ear canal, and with no history of undue exposure to noise. Further progress in standarization has occurred subsequent to R389 with the revision of the British standard in 1968-69 and the adoption of the American audiometer standard (ANSI, 1969).

The improvements in the specification of auditory threshold for the calibration of audiometers co-exists with some imperfections, including the impossibility of allowing for such variations as the different volumes under different earphones, and the complicated and flexible shape of the external ear. Finally, the inherent variability of the human auditory threshold (either real, or as an artifact of the technique of earphone audiometry) is recognized by specifying the auditory threshold by some form of average, in this case the modal value.

In summary then, in audiometry, a scale, in dB, of hearing level is used, the zero of which corresponds to the normal threshold as defined by the standard in use. The zero level is automatically set by the audiometer for each frequency used, and the hearing level is defined as the deviation in decibels of an individual's threshold of hearing from the standard. A clinical examination of the ears should be done in conjunction with audiometry, as such factors as wax in the ear canal or a head cold can throw considerable doubt on the reliability of the audiogram.

b) **Maintenance of Calibration**

Audiometers must be kept in proper condition in order to produce reliable results. They must be maintained and checked for acoustic output and adjusted or calibrated at regular intervals. When calibration by means of an artificial ear is not possible, then biological calibration with a group of normals, or with a subject of known hearing level may be used.

c) **Background Noise**

Limitation of background noise is important for reliable audiometry, as excessive noise will interfere with the audibility of test tones, a condition known as masking. One thus desires a test enclosure with a suitable safety margin below the auditory threshold. The maximum allowable background noise levels for an audiometric test area, as published in the Ontario Ministry of Health Booklet "Occupational Audiometric Testing Programs" are listed in Table I. These are similar to the American ANSI standards with a safety factor of 10 dB.

Table I

Maximum Allowable Background Noise Levels for Audiometric Test Areas

Octave Band (Centre Frequency, Hz)					
500	1,000	2,000	4,000	6,000	8,000
30	30	37	47	57	57
Sound Pressure Level (dB) re 20 μPa					

d) **Sources of Error in Audiometry**[4]

The sources of variability in audiometry may be divided into 2 categories. One is the true variability of hearing threshold. The other is compounded of factors comprising the variability due to the size of the ear canal, the position and pressure on the ear of the earphone, and the subject's judgement of his auditory threshold on the occasion of the particular measurement.

The uncertainty of single audiometric measurements is considerable and is influenced by the skill and practice of the listener. Where greater accuracy is required, there is no alternative but to repeat the measurements, readjusting the headphones so as to minimize the error due to placement.

Burns[4] quotes a number of studies done to assess test to test variability on subjects not expected to have any actual change in hearing level between tests. The results of these studies were in close agreement and, in general, both the standard deviation of an individual subject about his mean and group standard deviations are comparable at about 4 dB. Thus, with these values, for the range 500-4,000 Hz, 95% of the observations of an individual's threshold should fall within plus or minus 8 dB of his mean threshold. In the case of noise-exposed persons the replication variances are appreciably larger than in persons not exposed, and they increase with increased noise exposure.

With careful, well-conducted audiometry, in quiet surroundings and with well-maintained audiometers, changes of 10 dB between audiograms should be regarded as possibly significant.

e) **Normal Hearing**

"Normal" hearing is a statistical concept; distribution of values of auditory threshold conform reasonably closely to the concept of the statistical normal distribution, with the standard deviation for the threshold being 6-7 dB in the audiometric range of frequencies. This means that at 1,000 Hz, for example, 5% of people with apparently quite normal hearing will differ in hearing level from the standard value by 12-14 dB. This range of hearing levels is due to a combination of true biological variation and variation of an instrumental nature related to the use of earphones.

f) **The Effect of Age on Hearing**

As humans age, there is a progressive deterioration in hearing level for high tones. This phenomenon, known as presbycusis, is illustrated in Figure 5. It is routinely found in surveys that presbycusis is more marked in men than in women. The consensus is that this is not a biological effect, but is rather related to the higher lifetime vocational and avocational exposure of males to noise.

While uncomplicated cases of hearing deterioration due to noise or to age can be clearly distinguished by the usual clinical methods, it is necessary to recognize the possible difficulties of demarcating normal hearing from hearing impaired to a moderate degree by noise, especially in older people.[5] The noise environments of work, or even of some recreations, may be such that sufficient noise exposure may be sustained to produce degrees of hearing loss in excess of that which would accrue from age alone at frequencies in the region of 4,000 Hz. When we recall that normal hearing lies within an appreciable range of hearing levels at each frequency, and that susceptibility to noise-induced hearing loss has a wide individual variability, any single audiogram may leave considerable uncertainty as to the condition and previous history of the person's hearing.

To the present, it has been customary to assume that the effects of age and of noise are additive in a simple manner, the implication being that the mechanisms are different to a significant degree. Burns[5] cites Glorig and Davis[6] for support of this idea. These men investigated hearing level, as a function of age, by both air-conduction and bone conduction audiometry. They concluded that a part of the presbycusis deterioration is in the middle ear, and therefore distinct from the deterioration due to the effects of noise on the inner ear. Other components of presbycusis are believed to exist: deterioration of hearing from physical changes in the cochlea, from neural changes in the cochlea, and from aging processes in the brain. Nevertheless a significant component appears to be associated with the middle ear at ages when senile changes are not conspicuous in the hearing mechanism. This being so, subtraction of the presbycusis allowance from the measured hearing level appears to be permissible in attempting to estimate the effect of noise.

Due to the various unassessable factors involved, this process may give erroneous results in the case of individuals, but is useful in the case of average figures for groups.

NOISE AND HEARING

The effects of noise on hearing may be temporary or permanent, and the principle index of the existence of these effects has been changes in hearing sensitivity or threshold hearing levels. If the change in hearing sensitivity is reversible and recovers to pre-exposure levels within some time interval following the noise exposure, it is called noise-induced temporary threshold shift (NITTS). If the loss of hearing sensitivity resulting from exposure to hazardous noise persists throughout the lifetime of the affected person, then it is called noise-induced permanent threshold shift (NIPTS). When the threshold shift is permanent, there is no possibility for further recovery of hearing.[7]

Permanent threshold shifts may result from acoustic trauma or may be the result of an accumulation of noxious effects of noise exposures repeated over a period of many years. The primary damaging mechanism seems to be metabolic stress on the maximally stimulated sensory cells and this is an area of active ongoing research.

People are not affected uniformly by similar noise experience, and the amount of hearing loss sustained by people working in apparently similar noise conditions varies considerably.

Most of the laboratory investigations concerning noise and hearing have dealt with TTS and its relationships. The hypothesis that susceptibility to noise-induced temporary threshold shift is directly related to susceptibility to NIPTS has not proven valid, and so at the present time, no predictor of susceptibility to NIPTS is known. TTS is, nevertheless, a phenomenon of both academic and practical interest, as, for example, significant residual TTS could adversely affect a worker's leisure hours.

TEMPORARY THRESHOLD SHIFT

The production of temporary threshold shift and the recovery from the temporary change in hearing sensitivity depend upon a multiplicity of factors, and these will be discussed below.

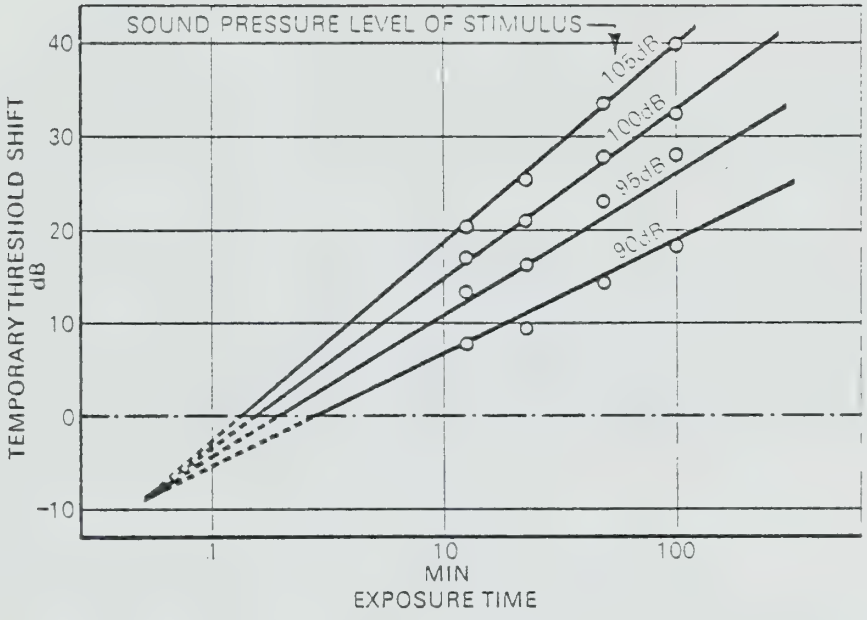
a) Frequency

The higher the exposure frequency, the more TTS is produced by comparable exposure levels. This observed relationship is reflected in most damage-risk specifications, which permit exposure to higher levels of low frequency noise than would be acceptable in the mid-frequency range 600-2,400 Hz. It is also consistent with using the A-weighted scale in sound level meters to serve as the index of hazard of the noise environment.[8]

b) Intensity

The amount of TTS increases with the intensity of the sound, but is also directly related to the duration of the noise. The interaction of sound intensity and duration of the stimulating sound underlies the important concept of exposure. In considering the effects of noise on hearing, neither sound intensity nor sound duration can be considered alone; they should be considered together as sound or noise exposure.[8] This is illustrated in Figure 6.

Figure 6



Temporary threshold shift at 4,000 Hz, 2 minutes after the end of exposure to a band of noise of 1,200 to 2,400 Hz at the sound pressure levels and durations indicated.

Robinson[14] has introduced the concept of "noise immission" as a measure of noise exposure, taking into account both noise level and duration. In his studies, to be discussed later, he found that immission was the noise parameter which could be used in predicting population hearing levels. Immission (in dB) is defined by the equation:

$$E\,(dB) = L_A + 10 \log T$$

where L_A is the A-weighted noise level and T is the exposure time in years.

As this is a logarithmic relationship, the immission is related to the product of L and T.

There is a sound level at which noise will neither produce an appreciable threshold shift, nor retard TTS recovery, regardless of its duration. This level, in effect, defines a noise exposure and a sound environment which could be called "effective quiet". Ward, Cushing, and Burns[9] investigated this phenomenon and showed this level to be about 76 dBA.

c) Exposure Pattern

The relationship of TTS to sound exposure increases in complexity when the stimulating sound is intermittent or fluctuating as opposed to steady state. Generally, TTS from intermittent sound is less than if there had been continuous exposure to the same sound.

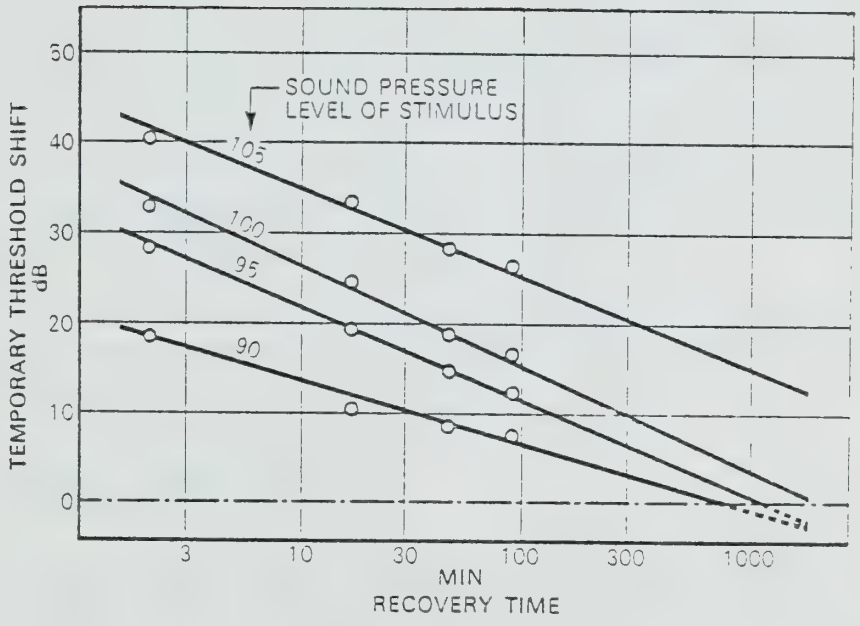
d) TTS Due to Impulsive Noise

This type of noise is characterized by sudden, short duration noises which may be repeated at various frequencies. The repetition frequency is important from the viewpoint of TTS and, presumably, of damage to hearing. The aural reflex muscles have a latent period of about 10 msec, insufficient to establish fully the protective function with impulses of short rise time. One single intense, sudden sound can damage the ear before the protective reflex has time to act. For impulses that are separated by less than one second, the protective effect of middle ear muscle contractions is an important factor, reducing the amount of TTS produced.

e) Recovery from TTS

The recovery of hearing acuity following noise exposure depends in part upon the magnitude of TTS. For recovery which is complete within 16-24 hours post-exposure, the recovery is linear as a function of the logarithm of time. This is illustrated in Figure 7.

Figure 7



Recovery from temporary threshold shift at 4,000 Hz, at various intervals after the end of exposure to a band of steady noise of 1,200 to 2,400 Hz, at the sound pressure levels indicated, and for the same exposure duration. The lines are fitted by the method of least squares.

This type of recovery might be expected to result from modest levels of exposure in which TTS does not exceed 40 dB. Delayed recovery has been observed when TTS produced by a single exposure exceeded 40 dB or when subjects were exposed to moderate intensities for fairly long periods.[10] If the sound exposure is extremely intense or extremely long, it is possible that complete return to pre-exposure levels will not occur and a permanent hearing loss will result. Sound exposure conditions which result in delayed recovery are considered to be particularly hazardous to hearing.

f) Susceptibility to TTS

Burns[11] discusses the problem of susceptibility to noise effects. Historically, the hope has been to discover a relationship between susceptibility to TTS and the development of permanent loss, with the hope of screening out those particularly susceptible and protecting them from damaging exposures. To date no practical fulfillment of this desire has been found but a statistical relationship involving groups has been postulated; that is, that the average permanent noise-induced threshold shift resulting from daily exposure to a particular noise for 10 years is approximately equal to the average TTS produced in young normal ears by an 8-hour exposure to the same noise.

It must be emphasized that this is a group statistical result and is not applicable to individuals.

g) Occupational Implications of TTS

Apart from its theoretical implications as a harbinger of permanent damage, the phenomenon of TTS as a result of a day's exposure to noise may have direct impact upon the worker. As seen in Figure 7, the recovery time from significant levels of TTS may extend well into a worker's leisure time with the possibility of interfering with his enjoyment of leisure activities. Should a worker already have damaged hearing, this additional loss due to TTS could push him temporarily into the realm of impairment.

Thus, while by definition, noise-induced temporary threshold shift always recovers, it does have the potential to detract from the quality of life.

PERMANENT EFFECTS OF NOISE ON HEARING

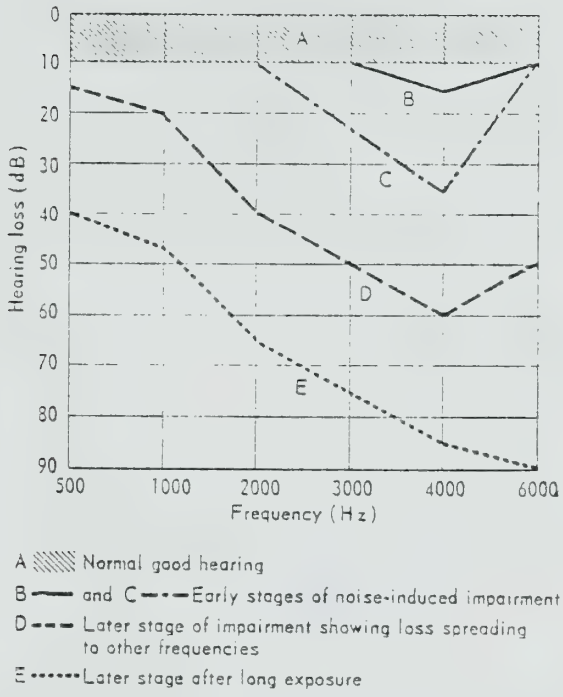
Information available on noise-induced permanent threshold shift (NIPTS) in humans has come from field studies, particularly in industrial environments. These studies suffer from a lack of experimental control, as the investigator cannot be sure whether the measured hearing loss is, in fact, the result of exposure to industrial noise or to the other factors known to cause hearing loss. All other variables must be eliminated as much as possible if field measures of hearing loss are to have much value. The major recent industrial studies have taken care to eliminate from the statistics all workers with abnormal hearing attributable to any other cause but noise. The majority of these studies are cross-sectional in nature; that is, they study all subjects at one point in time and attempt to relate findings to past conditions and individual histories. Despite all of its weaknesses, this type of research provides the only information we have about the permanent effects of noise on hearing, and provides the basis for current standards and damage-risk criteria.

a) Hearing Loss Pattern

Hearing loss resulting from the hazardous effects of noise, particularly in the typical industrial noise environment, progresses in a well established, recognize able pattern, illustrated in Figure 8.

Figure 8

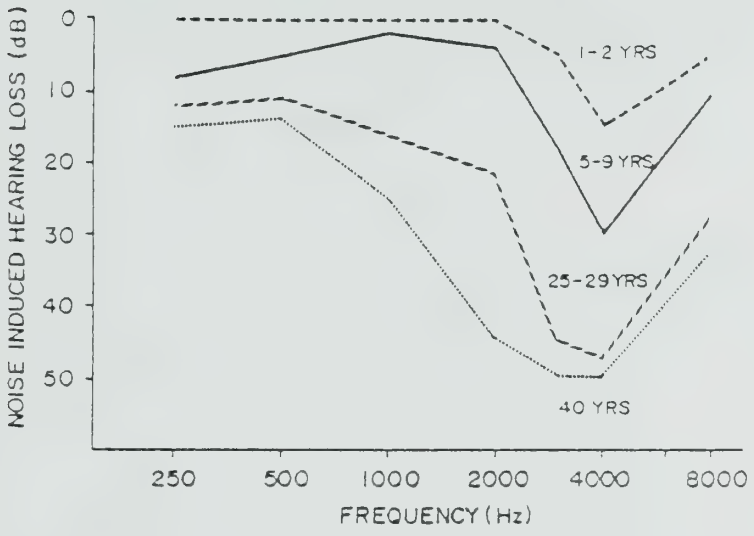
AUDIOGRAMS SHOWING DIFFERENT STAGES
OF NOISE-INDUCED HEARING LOSS



The first indication of damage is an asymptomatic dip in the audiogram at 4 kHz. As the exposure to hazardous noise continues, this decrease in sensitivity at 4 kHz increases, but the hearing loss continues to occur in the rather restricted frequency range of 3-6 kHz. With further noise exposure, the rate of decrease in hearing sensitivity at 4 kHz decreases, but now the hearing loss spreads to frequencies above and below the 3-6 kHz band. At this point the handicap produced by the noise-induced hearing loss becomes apparent to the affected person, and is manifested as difficulty in understanding speech, especially in a noisy background.

Figure 9 shows this response in a group of female jute weavers who had worked in the same setting for periods from 1-52 years in apparently relatively constant noise conditions.[12]

Figure 9



There are large differences in individual susceptibility to NIPTS. Within a group of people who are apparently similarly exposed, some people may exhibit extensive hearing loss while others may be minimally affected. The variability in NIPTS increases with increasing audiometric test frequency and with increased exposure duration.

The variance observed in permanent hearing loss caused by noise exposure can, in part, be attributed to individual differences in susceptibility to the effects of noise. It also results from the variation inherent in the many procedures for measurement of theshold hearing sensitivity and, in part, from the actual differences in the noise levels encountered.

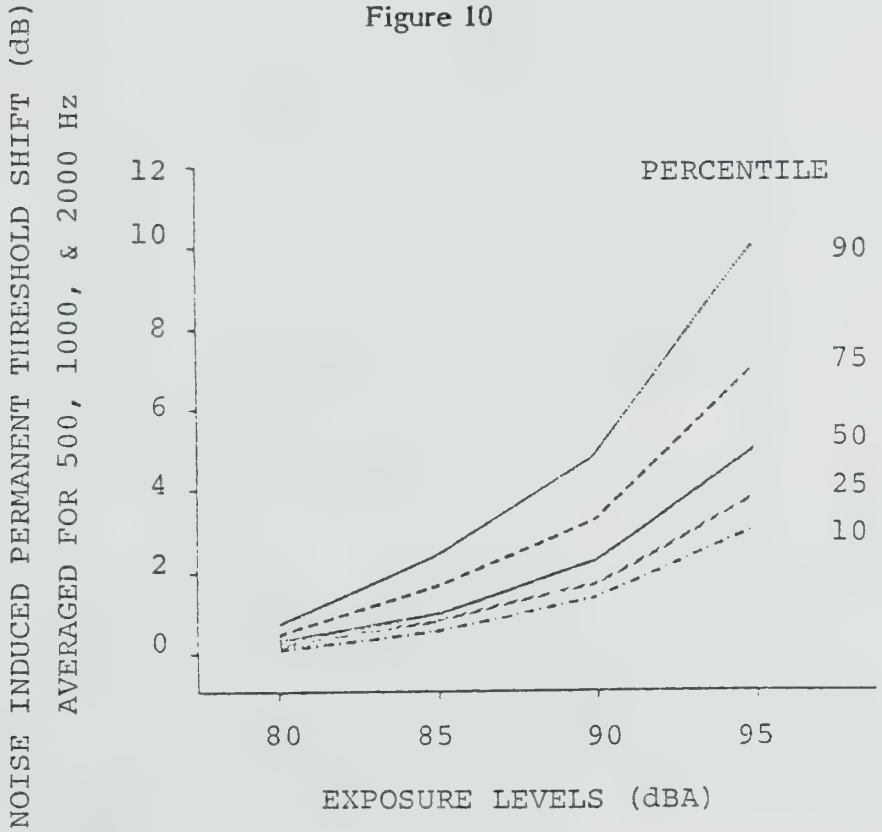
FACTORS INFLUENCING OCCUPATIONAL HEARING LOSS

a) Noise Intensity

If all other factors are held constant, NIPTS increases as the level of the offending noise increases. Johnson[13] has examined three large industrial studies and averaged their predictions of NIPTS, after 40 years of noise exposure, for various population centiles.

His results are presented in Figure 10. As can be seen from this figure, NIPTS increases with noise level, as does the spread in range of hearing values.

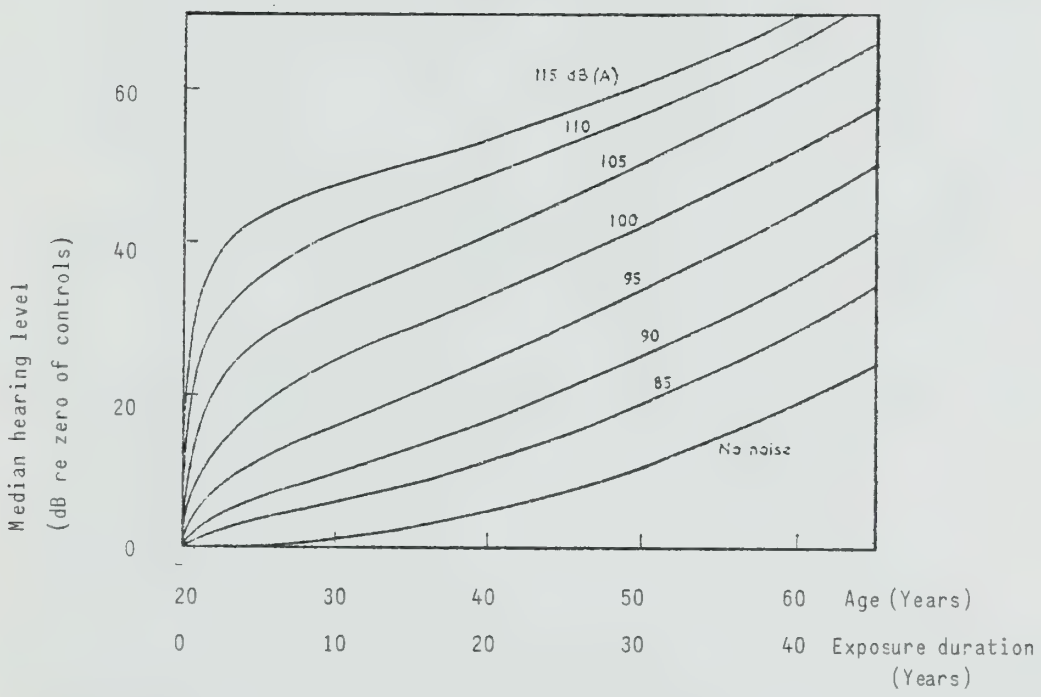
Figure 10



Distribution of noise-induced hearing loss as a function of A-weighted noise level. These levels are adjusted for presbycusis.

The effect of age, noise level, and time is shown on a graph (Figure 11) taken from the major British Industrial Study of Burns and Robinson.[14] Median hearing level at 4 kHz is shown and the effect of noise can be seen by subtracting the level of the controls, shown as the bottom curve.

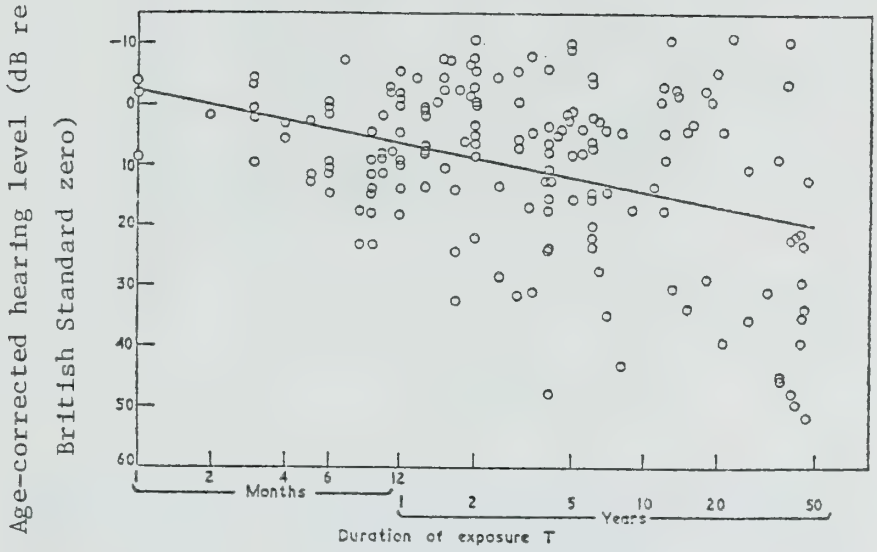
Figure 11



Development of hearing deterioration as a result of age and noise exposure, the latter being assumed to begin at age 20. Values are calculated from Robinson.[9] Parameter is A-weighted sound level of the occupational noise Audiometric frequency 4 kHz.

Figure 12, from the same study, shows the increasing scatter with duration of exposure.

Figure 12

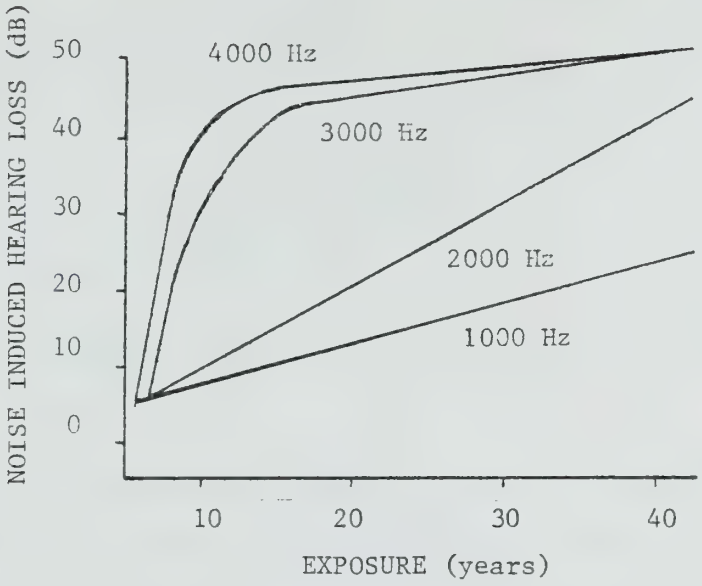


An illustration of the scatter of values of one corrected hearing level for different durations of exposure.

b) **Exposure Duration**

The various auditory frequencies are affected at different rates by noise. As mentioned previously, the first indication of noise damage is a dip at 4 kHz on the audiogram. The study by Taylor[12] depicted in Figure 8, has been used to derive Figure 13, which shows the time-behaviour of the various audiometric frequencies in a relatively constant noise environment. It can be seen that losses at 3 and 4 kHz tend to rise and plateau quickly, while the lower frequencies deteriorate slowly but inexorably.

Figure 13



Development of noise-induced hearing loss at indicated test frequencies as a function of duration of occupational exposure. These curves have been simplified and smoothed to illustrate the pattern of hearing loss development. No provision should be attached to the numbers.

c) **Time-Varying Noise Levels**

Information on the effects of non-steady noise that is intermittent, fluctuating, or impulsive is scarce.

The proponents of the "equal-energy hypothesis" feel that equal amounts of A-weighted sound energy produce equal amounts of damage irrespective of the temporal distribution of the noise - thus, for example, 100 dBA for 8 hours daily produces the same damage as 103 dBA for 4 hours daily in the industrial setting. For non-steady noises, they feel that the integrated sound energy over the course of the day is the parameter of interest, and they call this Leq, the equivalent - continuous sound level. Formally, L_{eq} is given by:

$$L_{eq} = 10 \log \frac{1}{T} \int_0^T \frac{P_A(t)^2}{P_o^2} \, dt$$

Where T is the length of the day
P_A is the A-weighted sound pressure
and P_o is 20 micropascals.

Use of this concept leads to a 3-dB trading relationship between noise level and time.

Some authors feel that the results of TTS experiments can be used to predict the hazards of various noise patterns; noises producing the same TTS should be treated as equally hazardous. Robinson[25] however shows that this approach can lead to paradoxical results and presents a strong argument that the results of TTS experiments can not be extrapolated to predict long-term occupational effects.

HEARING LOSS AND IMPAIRMENT

A major and fundamental question that arises when considering noise and hearing is: What is it that we are trying to protect, and how do we measure this property? In this context it is useful to introduce the following commonly used definitions:

1. Impairment - deviation or change for the worse in either structure or function, usually outside the range of normal.

2. Handicap - the disadvantage imposed by an impairment sufficient to affect one's personal efficiency in the activities of daily living.

3. Disability - the actual or presumed inability to remain employed at full wages.

In contemporary practice, hearing is measured by pure-tone audiometry in a quiet room. How does a departure from normal hearing affect one at a concert, watching television in a noisy pub, or conversing in a group at a party? It is currently accepted that pure-tone audiometry is the only practical form of hearing testing, but its interpretation in terms of impairment, handicap, and disability is extremely controversial, and the uncertainties in setting a standard are magnified by these controversies.

The ideal world would be one in which a worker's hearing would be totally unaffected by his occupation, which effectively means that the sound environment at work be essentially no different from the ambient environment. In terms of the language of the temporary threshold shift, we have seen that an "effective quiet" is an environment with a sound level of 76 dBA. It is apparent that achievement of this level in the near term is beyond reasonable hope.

What, then, should be the goals for the conservation of hearing? The earliest sign of damage on the audiogram is the 4 kHz dip. If one chooses a goal of no impairment of hearing, the ability to hear faint sound at 4 kHz should be preserved. Many observers, however, believe that the ability to hear faint sounds in the range 3-6 kHz is not an important function in everyday life. Commonly, there is no handicap in everyday life, including the appreciation of music, in the presence of moderately large impairments of sensitivity for these frequencies.[15]

The universally agreed upon concern is that hearing capacity required for speech and communication should be preserved. Major areas of dispute and uncertainty exist as to how this ability should be determined. The technique of "speech audiometry" is not widely standarized or accepted, and so the universal technique employed to gauge impairment is the pure-tone audiogram. The physiology and psychology of human hearing is very complex and a multitude of formulae have been proposed and adopted to determine hearing impairment in the "speech range". None of these formulae can claim "scientific truth" and different ones are used throughout North America and the world.

In their search for a medico-legal definition of hearing impairment, the American Academy of Ophthalmology and Otolaryngology considered no impairment to be present if the average of the hearing thresholds for the frequencies 0.5, 1, and 2 kHz was 25 dB or less. Above this level, impairment was considered to increase by 1.5% per dB up to 100% impairment at 93 dB.(16)

Direct tests of the ability to discriminate speech for the purposes of a scale of impairment were seriously considered, but rejected because of the complexities of speech perception.(17)

Several investigators(18) have concluded that the average loss of sensitivity at 1, 2, and 3 kHz correlates better with loss of speech intelligibility, in noise, for tne hard of hearing than does the average loss at 0.5, 1 and 2 kHz, and Professor Alberti of the University of Toronto concludes that formulae used for assessing compensable hearing loss should include higher frequencies, at least 3 kHz, as this is more closely related to speech discrimination. In any complex listening circumstances with background noise, as is common in everyday life, there is a demonstrable handicap if hearing in frequencies above 2,000 Hz is impaired. He prefers the British scheme of measurement at 1, 2 and 3 kHz, with a compensation fence at 35 dB.(19)

In Ontario, currently, the Workmen's Compensation Board allows a claim for compensable deafness if the average hearing level of the four speech frequencies (0.5 kHz, 1 kHz, 2 kHz, and 3 kHz) minus a presbycusis factor of ½ dB for each year of age over 60 is greater than, or equal to 25 dB.(20)

That is, a claim is allowed if

$$\tfrac{1}{4} \left[\text{level at } 500 + 1{,}000 + 2{,}000 + 3{,}000 \right] - \tfrac{1}{2} \left[\text{age} - 60 \text{ years} \right] \geq 25 \text{ dB}$$

The loss is considered pensionable if it is 35 dB or more.

The social ramifications of these numbers are far from obvious. Kell(21) conducted a survey of Scottish women who had worked as weavers for a minimum of 20 years in a mean occupational noise level of 100 dBA. Controls were drawn from the same towns as the subjects and were age-matched to within 5 years. Pure tone audiograms

measured at 0.5, 1 and 2 kHz showed an average loss of 37 dB for weavers and 13 dB for controls, while speech audiometry showed that the weavers, at all ages, had a poorer understanding of speech than the controls.

The social consequences of this impaired hearing ability were:

a) difficulty at public meetings (weavers 72%, controls 6%)

b) difficulty talking with strangers (weavers 80%, controls 16%)

c) difficulty talking with friends (weavers 77%, controls 15%)

d) difficulty understanding the telephone (weavers 64%, controls 5%)

e) 81% of all weavers considered that their hearing was impaired vs 5% controls

f) 9% of weavers and no controls owned hearing aids

g) 53% of weavers and no controls used a form of lip reading

We thus have a situation in which one can quite well measure the effects of noise on the ear with the pure-tone audiometer. It remains far from clear, however, how these measurements correlate with social disability and detriment to the quality of life. Much more work needs to be done, and this is an active area of research in the field of audiology.

INDUSTRIAL STUDIES OF STEADY NOISE EXPOSURES

In the past 15 years, several major industrial studies have been done in an attempt to discover the relationship between noise exposure and hearing loss. As a result of these studies, it has become possible to make predictions about the effects of continuous noise on a population of exposed workers. There is a high degree of individual variability, and no predictive formulation is as yet available for individuals.

The studies which have received the most attention in the literature will be described in the next section of this chapter.

The Major Studies

I. Passchier-Vermeer collected data from several Dutch industries and used literature data from British and American studies, constituting about 4,500 workers in 20 groups.[22, 23] She calculated hearing levels for the median and various centile fractions of the exposed populations as a function of noise level and exposure time after making presbycusis corrections. These enable predictions to be made of population hearing levels after exposure in various noise levels. She concluded that 80 dBA was effectively a safe exposure, while a level of 90 dBA gave a chance of considerable hearing damage in a rather large percentage of employees.

This study has been criticized on several grounds. The authors of the recent American Inter-Industry Noise Study[24] feel that few of the studies she used in her work were designed to be used as a basis for a noise standard and each has flaws. Robinson[25] feels that she averaged discordant data and that the results of her manipulations are not adequately reliable.

II. The Study of Baughn[26] published in 1966 is an analysis of 6,835 audiograms from employees of an American auto-parts plant. The audiograms were assigned to groups called "78 dB(A)", "86 dB(A)", and "92 dB(A)" depending upon which of these noise levels the particular worker's average exposure seemed to be the closest. Baughn's results have been criticized as likely to be affected by both TTS and the effects of masking in the audiometry room, both of which would tend to make his predictions of NIPTS too high.[27]

Robinson[25, 28] points out that agreement with his data (to be discussed below) is far from perfect, but turns out to be remarkably well-ordered, in that a numerical shift of one data field by a nearly constant amount (12± 1.5 dB) brings the two into alignment over a considerable range of the parameters. He suggests that this difference is due to Baughn's use of an unscreened population in combination with the effects of TTS and masking.

Baughn's work forms the basis for the I.S.O. recommendation R1999 (1971).

III. The Study of Burns and Robinson[29]

This major industrial study was supported by the British government and forms the basis for the B.O.H.S. standard for wideband noise.[30] It was a carefully designed and performed study of 759 workers exposed from one month to 50 years in carefully assessed noise fields. Workers were screened to exclude otologic disease. The results were elegantly expressed in terms of a single mathematical expression, with adjustable parameters, that enables predictions to be made of hearing level as a function of population centile, age, noise level and duration of exposure.

Johnson[31] in a study for the U.S. Environmental Protection Agency used the data bases of Baughn, Passchier-Vermeer, and Burns and Robinson to calculate an average noise effect. He found that it didn't make too much difference in the final result if one or two of these data bases was discarded, or if the Burns-Robinson study was taken alone. He found that taking all three gives an average that usually differed from any of the three individual methods by less than 5 dB.[32]

Johnson's results are presented in terms of centile losses. The maximum NIPTS of the 90th percentile is the level not exceeded by 90% of the population. Table 2 from his work gives a summary of the permanent hearing damage effects expected from exposures at various values of the A-weighted sound level for a working lifetime, expressed as an average over the various speech frequencies and at 4 kHz. A trend of increasing loss with noise level is apparent.

Recall that the frequency combination used by the Ontario Workmen's Compensation Board is the average at 0.5, 1, 2, and 3 kHz.

TABLE 2

Summary of the Permanent Hearing Damage Effects Expected for Continuous Noise Exposure at Various Values of the A-weighted Average Sound Level

	av. 0.5, 1, 2 kHz	av. 0.5, 1, 2, 4 kHz	4 kHz
80 dB for 8 hrs.			
Max. NIPTS 90th percentile	1 dB	4 dB	11 dB
NIPTS at 10 years 90th percentile	1 dB	3 dB	9 dB
Max. NIPTS 10th percentile	0 dB	0 dB	2 dB
85 dB for 8 hrs.			
Max. NIPTS 90th percentile	4 dB	7 dB	19 dB
NIPTS at 10 years 90th percentile	2 dB	6 dB	16 dB
Max. NIPTS 10th percentile	1 dB	2 dB	5 dB
90 dB for 8 hrs.			
Max. NIPTS 90th percentile	7 dB	12 dB	28 dB
NIPTS at 10 years 90th percentile	4 dB	9 dB	24 dB
Max. NIPTS 10th percentile	2 dB	4 dB	11 dB

IV. Martin, Gibson, and Lockington published the results of a study at Dominion Foundries and Steel Limited in Hamilton.[33] They measured the hearing of workers in several well-defined areas of the plant and made careful noise surveys in these areas. Controls consisted of office staff with a minimum of occupational noise exposure. They calculated an "average audiogram" for workers in each of four age categories and compared these with controls. They also calculated values of the hearing loss index averaged at 0.5, 1 and 2 kHz.

The authors conclude that at exposure between 85 and 90 dBA the risk of impairment is increased from 4-20% over that of controls. An examination of their data reveals, however, that because of small numbers of subjects, the differences in hearing loss index are not statistically significantly different when the exposed group is compared to controls. Although calculations are not presented, differences at the higher audiometric frequencies of 3, 4 and 6 kHz do appear to be of borderline statistical significance, using an estimate of the appropriate standard deviations taken from the Inter-Industry Noise Study. This implies that a noise effect is indeed present between 85 and 90 dBA and that one might expect to see impairment in the more susceptible workers.

V. NIOSH, as part of the background work for their criteria document[34] collected data from industrial workers in 13 surveys from 1968 to 1971. They eliminated workers not exposed to a specified continuous noise level over their working lifetime and those with hearing loss from medical and otological problems, leaving them with audiograms from 792 exposed and 380 control employees. Data was assumed to be distributed in a Gaussian distribution and was fit to a normal curve. They then calculated from this model the percentage of employees expected to exceed any particular hearing level, and calculated a risk by subtracting the number of non-exposed employees expected to exceed this level.

They conclude that at retirement age, when compared to controls, 15 workers in 100 will have suffered impairment if exposed to 85 dBA, while 30 in 100 will be impaired if exposed to 90 dBA, with the index of impairment being the average loss at 0.5, 1, and 2 kHz being greater than 25 dB.

Details of their work are very sketchy and one can't assess the reliability or statistical significance of their results.

VI. The Inter-Industry Noise Study[24]

This recently published American study examined the effects upon hearing of steady state noise between 82 and 92 dBA. Workers were carefully selected according to a protocol to ensure the exclusion of pathological ears and to select workers in steady noise exposure. A large potential population was considered, but only 155 experimental males and 193 experimental females were found meeting their criteria. These were matched against controls exposed to 75 dBA or less. Although, it was hoped that noise exposures would be constant within a 6 dB range, it was found on follow-up visits that this was not the case.

Results are presented in terms of age-adjusted mean hearing levels, and they found that the men's hearing levels were statistically significantly higher than those of the controls at 3, 4, and 6 kHz, while those of the women were never significantly different from their controls.

The average noise level in this study was 87.7 dBA, and the results imply that a noise effect is evident in men at this level. Results are presented only in terms of mean levels, so it isn't possible to comment upon impairment in the more susceptible segments of the population. The significance of the lack of difference between the experimental women and their controls is difficult to assess. Studies in higher noise fields have shown that women do suffer noise-induced hearing loss, so that two possible interpretations are that women are more resistant than men to the effects of noise at this level or that the changes in the men are related to non-occupational factors.

Schori and Johnson[35] used the original data tapes for an independent analysis and came to the conclusion that the experimental subjects <u>are</u> significantly different from the controls. They do not comment upon the sex difference except to mention that the women do have better hearing at all levels. From their non-linear multiple regression analysis they present their estimates of the mean NIPTS expected after 15 years of occupational exposure at 87.7 dB. Comparisons with Robinson's predictions are presented in Table 3 below. The agreement is quite good.

Table 3

A comparison of Schori's estimates from the Inter-Industry Noise Study and the Predictions of the Burns-Robinson theory for 15 years exposure at 87.7 dB. Note use of median and mean.

Frequency	Mean NIPTS (Schori)	Median NIPTS
500 Hz	0.2 dB	1.0 dB
1,000	1.4	1.5
2,000	1.5	3.4
3,000	5.8	6.5
4,000	7.6	8.3
6,000	5.8	5.8

Similar agreement can be seen when comparing the data of Martin et al. with the predictions of Burns and Robinson.

VII. The Burns-Robinson (B-R) Study

In order to suggest an occupational standard for noise exposure, one is interested in predicting as well as possible the effects of noise upon a population of workers, since no predictions are yet possible for the individual. For this purpose we have chosen to use the formulation of Burns and Robinson which enables one to make predictions for any population centile based upon noise levels and duration of exposure.

The results of this study are presented in a mathematical form which enables calculation to be readily made: B-R found that for occupational exposures longer than one month (which was the shortest exposure in their study), they could relate the NIPTS to the amount of acoustic energy to which the ear was exposed. They named this quantity "noise immission" and defined the noise immission level by the equation:

$$E \text{ (dBA)} = L + 10 \log(T)$$

Where L is the sound level in dBA and T is the exposure time in years.

They found that they could reproduce the shape of the curves, such as those in Figure 12, showing NIPTS vs. exposure, with one equation containing two adjustable parameters depending upon audiometric test frequency and population percentile. This very elegant simplification allows universal calculations to be made for any frequency and any population centile for any combination of noise level and exposure duration.

The Burns-Robinson equation is

$$H_p = 27.5 \left[1 + \tanh \frac{E - F_f + U_p}{15} \right] + U_p$$

Where H_p is the age-corrected hearing level equalled or exceeded by p percent of the population,

E is the A-weighted noise immission level,

F_f is a constant depending upon the selected audiometric frequency, and

U_p is a constant depending upon the selected percentage, p.

Tables of these values, which greatly simplify application of the formula, have been published.[1, 14]

This formula is applicable to both men and women, but 1.5 must be added to F for women and 1.5 subtracted from F for men, reproducing the apparently more sensitive ears of men. The hyperbolic tangent is basically an S-shaped curve and its use reproduces the empirical characteristics of hearing loss, with its rapid initial rise and later plateau region.

Presbycusis

In order to determine the hearing level of a noise exposed worker, one must consider the effects of aging as well as those of noise. In general terms, exposure to noise can produce a loss of hearing acuity over a relatively short period of time and then approach a plateau, while the effects of aging begin slowly and proceed inexorably. The general consensus at the moment is that the effects of noise and aging occur at different anatomic locations, and so may be added independently, at least to the age of 65.

Many studies of presbycusis have been carried out, with more or less agreement. Corso[37] has published a study, employing careful screening and measurement, which gives mean hearing levels, with standard deviations, for a large American population. NIOSH[34] has proposed presbycusis corrections based on the surveys for their standards document. Their values, together with those of Corso, Martin, and the Inter-Industry study are shown in Table 4. There is reasonably good agreement, particularly in terms of the Hearing Loss Index, which is the average hearing level at 0.5, 1, 2 and 3 kHz.

Table 4

Presbycusis Data

Frequency (kHz)		Corso (37) Age 59-65 Mean	S.D.	NIOSH (34) Age 60	MARTIN (33) Age 50-65 (Controls)	I-I (24) Age 52 & above (Controls)
0.5	Male	7.1 dB	8.7 dB	17 dB	10 dB	10 dB
	Female	8.9 dB	12.4 dB	23 dB		12 dB
1	Male	9.0 dB	10.5 dB	11 dB	8 dB	11 dB
	Female	8.0 dB	13.2 dB	14 dB		10 dB
2	Male	18.4 dB	16.3 dB	13 dB	14 dB	19 dB
	Female	12.5 dB	13.7 dB	12 dB		13 dB
3	Male	31.8 dB	20.9 dB	23 dB	25 dB	18 dB
	Female	15.7 dB	13.7 dB	16 dB		13 dB
H.L.I.	Male	17 dB		16 dB	14 dB	18 dB
	Female	11 dB		16 dB		13 dB

H.L.I. = Hearing Loss Index = Average of 0.5, 1, 2, and 3 kHz.

In Ontario, currently the Workmen's Compensation Board accepts a claim as compensable if HLI exceeds 25 dB, and the claim is considered pensionable if HLI exceeds 35 dB. A presbycusis factor of ½ dB for each year over the age of 60 is deducted from the total.

As shown in Table 4, the average HLI at age 60 due to presbycusis, based on NIOSH values, is 16 dB.

This means that an additional NIPTS of 10 dB will lead to compensable hearing loss at age 60. We have made use of the Burns-Robinson equation and parameters to calculate the values in Tables 5 and 6 which show the NIPTS produced in various percentages of the population by noise levels of 85 and 90 dBA. As shown in Table 5, 25% of men exposed to a level of 85 dBA will suffer a NIPTS of at least 10 dB, while between 35% and 40% of men exposed to a level of 90 dBA will suffer a NIPTS of 10 dB, implying that an additional 10% to 15% of male workers risk impairment at a noise level of 90 dBA as compared to 85 dBA. The equal energy hypothesis proposes that this calculation can be extended directly to fluctuating or intermittent noise, if the noise level is expressed by Leq, the equivalent continuous noise level.

This analysis has been simplified by using the mean population values for presbycusis as it is not known whether or not there is any correlation between the effects of noise and aging. It is plausible that people with greater than average aging effects may also be more susceptible to noise, but they could just as well be more resistant. In the absence of any theoretical or experimental guidelines, I have assumed no correlation and used the mean value for presbycusis.

Because of the spread in hearing due to aging alone, one would expect a certain percentage of the non-noise-exposed population to exceed the 25 dB impairment fence, and using the values for the means and standard deviations from Table 4 one can calculate that 25% of the non-exposed population might be expected to meet the impairment criteria. Because of the lack of correlation information it is difficult to make an estimate of the absolute amount of risk at 85 dBA, but one can make the statement that the level of risk is increased by 10 to 15 men per hundred as the noise level is raised to 90 dBA.

Table 7, taken from the NIOSH criteria document, compares risk predictions from other sources. The exact values are sensitive to the definition of impairment, but a general result appears to be an increased risk of 10% to 15% between 85 and 90 dBA.

Table 5

Predicted Noise-Induced Threshold Shift for Men

A: Noise Level: 85 dBA

Predicted Hearing Levels exceeded by 25% of the population.

	Years exposure		
Frequency	20	30	40
500 Hz	5.7 dB	6. dB	6.3 dB
1,000 Hz	6.5 dB	7.3 dB	7.7 dB
2,000 Hz	9.6 dB	11.1 dB	12. dB
3,000 Hz	14.4 dB	16.8 dB	18.2 dB
HLI	9.1 dB	10.3 dB	11.1 dB

B: Noise Level: 90 dBA

(i) Predicted Hearing Levels exceeded by 40% of the population.

	Years exposure				
Frequency	5	10	20	30	40
500 Hz	2.5 dB	3. dB	3.6 dB	4.3 dB	3.2 dB
1,000 Hz	3.1 dB	3.8 dB	4.9 dB	5.8 dB	6.4 dB
2,000 Hz	5.1 dB	6.7 dB	8.9 dB	10.7 dB	11.8 dB
3,000 Hz	8.4 dB	11.3 dB	14.9 dB	17.8 dB	19.4 dB
HLI	4.8 dB	6.2 dB	8.1 dB	9.7 dB	10.2 dB

(ii) Predicted Hearing Levels exceeded by 35% of the population.

Frequency	20	30	40
500 Hz	4.7 dB	5.3 dB	5.9 dB
1,000 Hz	6.0 dB	6.9 dB	7.8 dB
2,000 Hz	10.4 dB	12.1 dB	13.6 dB
3,000 Hz	16.7 dB	19.6 dB	21.8 dB
HLI	9.5 dB	11.0 dB	12.3 dB

Table 6

Predicted Noise-Induced Threshold Shift for Women

Noise Level: 85 dBA

Predicted Hearing Levels exceeded by 25% of population at 40 years.

Frequency	Hearing Level
500 Hz	5.7 dB
1,000 Hz	6.5 dB
2,000 Hz	9.6 dB
3,000 Hz	14.4 dB
HLI	9.1 dB

Noise Level: 90 dBA

Predicted Hearing Levels exceeded by:

	40% of Population Years Exposure				30% of Population Years Exposure	
Frequency	10	20	30	40	10	20
500 Hz	2.5 dB	3.0 dB	3.4 dB	4.7 dB	4.3 dB	5.7 dB
1,000 Hz	3.1 dB	3.7 dB	4.5 dB	6.0 dB	5.0 dB	7.1 dB
2,000 Hz	5.1 dB	6.7 dB	8.0 dB	10.4 dB	7.4 dB	12.8 dB
3,000 Hz	8.5 dB	11.5 dB	13.5 dB	16.7 dB	11.4 dB	18.5 dB
HLI	4.8 dB	6.3 dB	7.4 dB	9.5 dB	7.0 dB	11.0 dB

Table 7

A Comparison of Risk Values

I.	This Calculation: dBA		85	90
	Percent impaired		25	35-40
	Excess Risk		0	10-15
	Impairment = Average: 0.5, 1, 2, 3 kHz > 25 dB			
II.	NIOSH Age: 55-70; Experience: 21-41 years.			
	a) HLI = Average 0.5, 1, 2 kHz > 25 dB; dBA:	80	85	90
	Total percent impaired	23	35	49
	Normal percent impaired (aging)	20	20	20
	Risk	3	15	29
	b) HLI = Average 1, 2, 3 kHz; dBA:	80	85	90
	Total percent impaired	30	43	56
	Normal percent impaired	27	27	27
	Risk	3	16	29
III.	I.S.O. Age 58; 40 years exposure HLI = Average 0.5, 1, 2, kHz > 25 dB; dBA:	80	85	90
	Total percent impaired	33	43	54
	Normal percent impaired	33	33	33
	Risk	0	10	21
IV.	Robinson[38] Age 60; 40 years exposure HLI = Average 0.5, 1, 2 kHz > 25 dB; dBA		87	92
	Noise Risk		7	14

The Trading Relationship

There is some controversy as to the appropriate trading relationship between noise level and exposure duration during the working day. Studies of long term industrial exposures appear to be consistent with the equal energy hypothesis that a given amount of acoustical energy produces the same amount of damage, no matter over what time interval it is delivered. This rule, which appears to be valid for industrial exposures of one month or more leads to a decrease of sound level of 3 dB for every doubling of exposure time, or an increase of 3 dB for every halving of exposure time. The 3-dB rule has been widely adopted in Europe.

Experimental work on TTS suggests that for fluctuating and intermittent exposures during the working day, the ear may be more tolerant than the 3-dB rule would imply. This has led to the alternative proposal of the 5-dB trading relation, as adopted by OSHA in the United States. The author of this review feels that the connection between TTS and permanent damage is speculative and on very shaky ground. The equal-energy hypothesis is consistent with the results of industrial studies and should be adopted as the basis of hearing conservation measures until such a time as it has been replaced by another scientifically established framework. It is in this light that the 3-dB trading relation is recommended.

Impact and Impulse Noise

Impact noise is noise characterized by a sharp initial transient produced by the collision of two or more masses, as in hammering or drop-forging, or by the sudden compression or rarefaction of a gas, such as by gunfire or explosions. The relationship of impact noise to hearing loss is an area of controversy in the literature. Most proposed damage-risk criteria are related to the noise of gunfire in the military setting and have little direct application to non-military occupations.

In the past several years, a few studies have been published of occupational hearing loss related to impact noise, primarily in the drop-forging industries, and these studies conclude that in the industrial setting the equal-energy principle can be applied to impact as well as to continuous noises. This work has recently been reviewed by Martin[39] who has shown that the Burns-Robinson formulation can be extended to the field of impact noise, providing a unity to the entire noise field.

Martin summarizes the 3 hypotheses accepted by the British workers:

1) Equal amounts of A-weighted sound energy cause equal amounts of damage to hearing.

2) Hearing damage is proportional to some function of the acoustical energy received.

3) A trading relationship exists between exposure time and noise level, the product of the two being a measure of the total acoustical energy received.

As we have seen previously, the noise immission level, E_A, is defined by:

$$E_A = L_A + 10 \log(T)$$

where L_A is the A-weighted sound level and T is the exposure time in years, on the basis of 8 hours/day, 5 days a week for 48 weeks.

For fluctuating noise levels, one can consider the concept of equivalent continuous sound level, L_{eq}, which is the hypothetical continuous sound level which would provide the same sound energy as the actual noise, if present over the actual working day.

$$L_{eq} = 10 \log \frac{1}{T} \int_0^T \frac{P_A(t)^2}{P_o^2} \, dt \qquad (1)$$

where T is the exposure time, P_A is the instantaneous A-weighted sound pressure, and P_o is the reference level of 20 micropascals.

The expression for immission level may then be expressed as

$$E_A = L_{eq} + 10 \log(T)$$

Figure 14 shows an oscillograph trace of a typical impact noise waveform, and this is presented schematically in Figure 15.

Figure 14

Impact - Noise Waveform

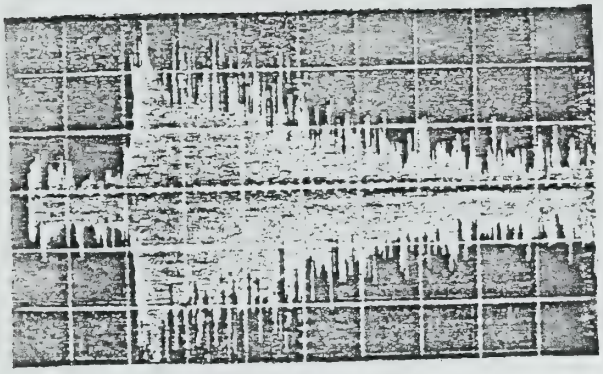
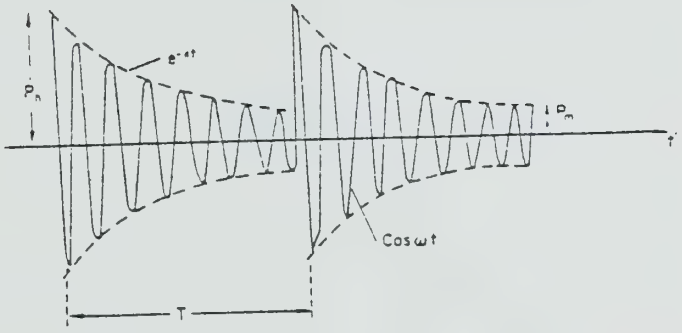


Figure 15



Recurrent impact noise shown as a modulated sinusoid.

As can be seen, impact noise has a sound pressure waveform which shows a high initial peak followed by positive and negative excursions within an exponential decay envelope. Atherley and Martin[40] calculated an expression for L_{eq} for impact noise by treating recurrent impact noise as a modulated sinusoid with an exponentially decaying envelope. Using the notation of Figure 15, the instantaneous pressure is:

$$P = P_h e^{-kt} \cos(\omega t)$$

where P_h is peak height, k is the decay constant equal to $1/t_e$, where t_e is the time taken for the waveform to decay to 1/e of its initial height, and ω is the frequency of the sinusoid.

The total sound energy E is proportional to

$$E \propto \int_0^T p^2 \, dt$$

On integration, this produces a rather complex expression which may be considerably simplified, as the terms containing ω tend to zero for frequencies greater than 200 Hz, producing,

$$p^2 = \frac{Rt_e P_h^2}{4} (1-e^{-2/t_e R})$$

where R is the repetition rate of the pulses.

Thus, from Equation (1), the equivalent sound pressure level (SPL):

$$SPL = 10 \log \frac{Rt_e P_h^2 (1-e^{-2/t_e R})}{4 P_o^2}$$

In most industrial situations, the exponential term will be vanishingly small, and so we drop it.

If we expand this expression using the rules for logarithms, then:

$$L_{eq} = P_h (dB) - 10 \log (4) + 10 \log (R) + 10 \log (t_e)$$

Artherley and Martin confirmed in the lab that this expression was independent of carrier frequency. It was also demonstrated empirically that this expression could be expressed in terms of an A-weighted level by subtracting 2.6 dB, which gives us:

$$L_{Aeq} = P_h \text{ (dBA)} + 10 \log (R) + 10 \log (t_e) - 8.6 \quad (2)$$

The question now arises as to whether the quantity

$$E_A = L_{Aeq} + 10 \log (T)$$

has the same predictive value for impact noise as its analogue has for continuous noise. The available studies show that indeed it does.

Atherley and Martin[40] studied 76 men exposed to drop-forging noise in 2 British factories. The parameters of the noise are presented in Table 8.

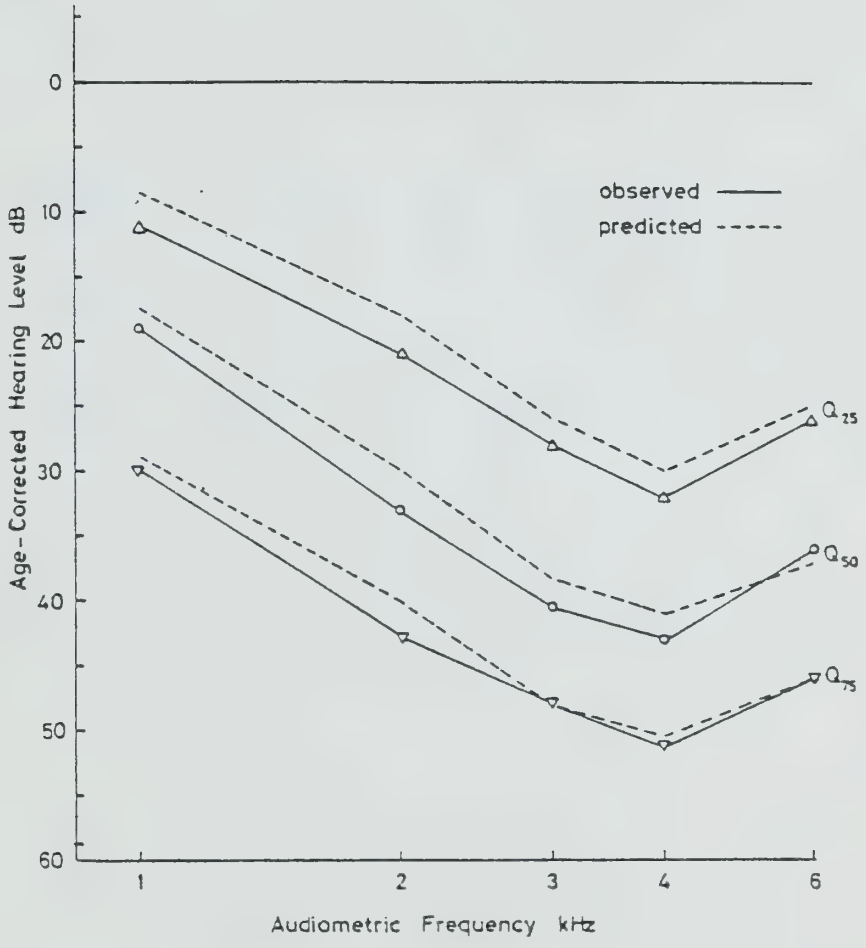
Table 8

Parameters of Drop-Forging Noise in the Atherley-Martin Study

Factory	Peak Height	Decay Time (t_e)	Impacts/day	L_{eq}
1	147 dB	0.045 sec.	5,700	118 dBA
2	130 dB	0.1 sec.	20,000	110 dBA

Figure 16 shows a comparison of median and quartile hearing levels observed by Atherley and Martin and predicted from the Burns-Robinson formulation.

Figure 16



As can be seen, agreement is excellent, perhaps too good considering the small number and the uncertainties involved; nevertheless, the implication is that the equal energy principal can be extended to the area of impact noise to predict the effects of occupational exposure.

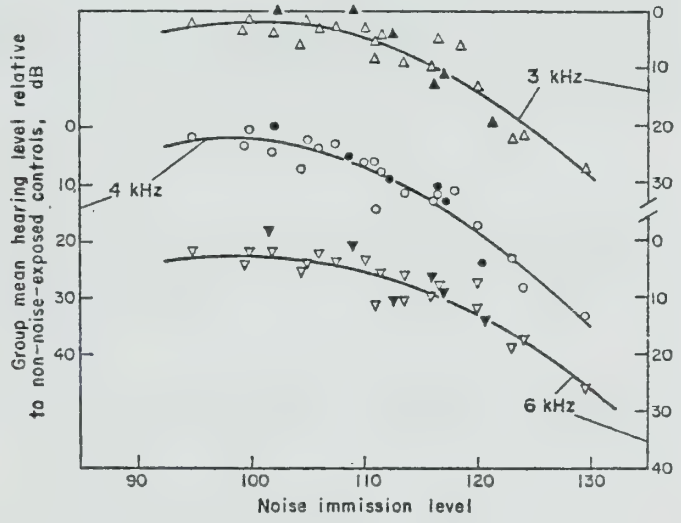
A similar study is that of Guberan et al.[41] who studied the hearing of 70 workers in 11 workshops in the drop-forging industry as well as 61 non-exposed controls.

They measured L_{eq} of the impact noises involved and calculated the immission levels of the workers. Peak pressure values varied between 108 and 120 dBA as measured with a "peak hold" sound level meter. Continuous noise in these factories varied between 65 and 75 dBA. Average decay time of the impacts was 100 milliseconds with a typical impact of 12 per minute for each press and about 20,000 per day for the shop.

Data was manipulated by multiple regression analysis in an attempt to take into consideration otological abnormality and gunfire exposure, and age corrections were made using British presbycusis data. Corrected mean hearing levels were then calculated for groups classified by noise exposure level. The mean audiograms thus calculated fail to show the typical 4-kHz notch, and if one calculates the standard error of the difference between the means, differences between experimental and controls are in many cases not statistically significant. The authors nevertheless calculate noise immission levels for their workers and compare their results with Robinson's model for continuous noise, i.e. the equal-energy concept. Their results are shown in Figure 17, and as can be seen are consistent with Robinson's data for continuous noise. This is another piece of evidence for the consistency of formulation.

Figure 17

Comparison of data from Guberan et al.(black figures) with that of Robinson (open figures). Guberan's workers were exposed to impact noise and Robinson's to continuous noise. For the impact noise, immission is calculated using equivalent continuous sound level.



A study by Ceypek et al.[42] is quoted by Martin.[39] These workers investigated the hearing levels of 213 drop-forgers exposed for up to 30 years. The impact noise parameters were studied with oscillographic techniques and the mean Leq of 116 dBA was calculated as described above. Hearing levels were found to be in agreement with predictions of the Burns-Robinson model.

Atherley[43] studied the hearing levels of 71 men exposed to the noise of pneumatic chisels. He found the distribution of hearing levels to be in agreement with predicted values.

Damage-Risk Criteria for Impact Noise

Although the studies quoted above can be criticized for being based on very small numbers of subjects and for using less than perfect analysis techniques, they provide the only data which allow one to predict the effects of impact noise on the hearing of workers. Using the concept of L_{eq}, the equivalent continuous sound level or level of continuous noise which contains the same sound energy over the working day as the impact noise, these studies suggest that the Burns-Robinson formulation for continuous noise can be used to discuss the effects of time-varying noise as well. Although the precise relationship between impact noise and hearing loss cannot be considered to have been established with certainty, the data discussed above are consistent with the Burns-Robinson formulation and the equal energy concept, and we will make use of it in discussion of an occupational standard.

The concept of risk has been discussed with respect to continuous noise and we can now carry this over to the realm of impact noises which produce equivalent continuous levels of 85 and 90 dBA.

As shown in equation (2), the equivalent continuous A-weighted level, L_{Aeq} is given by:

$$L_{Aeq} = P_h \text{ (dBA)} - 8.6 + 10 \log (R) + 10 \log (t_e) + 10 \log (1-e^{-2/t_e R})$$

A precise calculation of L_{Aeq} in any workplace requires the use of long-term integration techniques, dosimeters, or oscillographic techniques and this would certainly be the ideal approach. One can however make some approximations in order to arrive at a rapid and less elaborate assessment of hazard. In the studies of Atherley-Martin and Guberan et al. quoted above, an average value for t_e is 100 milliseconds. Assuming that this value from the drop-forging industry can serve as an approximation for values found in industry as a whole, then

$$L_{Aeq} = Ph \text{ (dBA)} + 10 \log (R) - 10 - 8.6 \quad (3)$$

Using equation (3), the values in Table 9 relating peak height to number of impacts in the working day can be calculated. In this calculation, R is the impact rate and equals

$$\frac{\text{number of impacts/day}}{\text{29,000 seconds/day}} = \frac{N}{29{,}000}$$

Consistency of formulation would require that a standard for impulse noise carry the same risk estimation as a standard for continuous noise. Using the equal-energy concept this can be achieved by thinking in terms of L_{eq} and noting that an equivalent noise level of 85 dBA carries the same risk as a steady noise level of 85 dBA.

Table 9

Peak Height Versus Number of Impacts

A) Equivalent Continuous Sound Level: 85 dBA	N	P_h (dBA)
	1	150
	10	140
	100	130
	1,000	120
	10,000	110
	100,000	100

B) Equivalent Continuous Sound Level: 90 dBA	N	P_h (dBA)
	1	155
	10	145
	100	135
	1,000	125
	10,000	115
	100,000	105

Conclusions

Noise is one of the industrial hazards that can be monitored by its physiological effects, allowing action to be taken before serious consequences have developed. The first indication of damage is the asymptomatic 4 kHz notch on the audiogram. In the susceptible worker this change will be apparent within 6-12 months of exposure to noise, and is always present before serious changes have taken place in the speech-reception frequencies. An early follow-up audiogram will thus permit the detection of susceptible workers in any given noise environment and allow appropriate action to be taken. Since the changes at 4 kHz appear quite rapidly if there is going to be any significant change, minimal deterioration on the initial follow-up audiogram would then imply that routine audiometry could then be done at 2-3 year intervals provided that no major changes took place in work-place noise levels.

A review of the literature shows a major trans-Atlantic difference of opinion with regard to noise theory. American workers base their thinking on the phenomenon of TTS while European workers seem to have accepted the equal-energy hypothesis. It is my opinion that the available industrial epidemiological data are consistent with the equal-energy hypothesis and that because of its powerful predictive capabilities this theory should be adopted as the frame-work for noise legislation, at least up to the time when it is shown to be invalid or is replaced by a superior theory.

Use of this theory predicts an increased risk of impairment of 10-15 workers per hundred when noise levels rise from 85 to 90 dBA. This is in basic agreement with the predictions of the ISO and of NIOSH. It is on this basis that it is recommended that the occupational standard be lowered to 85 dBA. Coupled with a hearing conservation program, this should provide substantial protection for the work force of Ontario.

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APPENDIX G

ADVISORY COUNCIL ON OCCUPATIONAL HEALTH AND OCCUPATIONAL SAFETY MEMORANDUM 79-III "CONCERNING OCCUPATIONAL HEARING LOSS: PREVENTION, COMPENSATION AND REHABILITATION"

and

THE MINISTRY OF LABOUR'S RESPONSE

AUGUST, 1980

Occupational Health
and Safety Division

Ministry of Labour

Advisory Memorandum 79-III

January 14, 1980

Concerning Occupational Hearing Loss: Prevention, Compensation and Rehabilitation.

INTRODUCTION

In consultation with the Minister of Labour, the Advisory Council on Occupational Health and Occupational Safety established the Task Force on Occupational Hearing Loss on January 9, 1979. *The minister noted three areas of concern regarding industrial deafness: prevention, rehabilitation, and the need to train paramedical personnel.* The council set out the task force's terms of reference in the broadest terms. These include:

1. To examine the current status of hearing loss in the Ontario work force.

2. To review the current status of preventive programs and to indicate the most effective short and long term options. In particular, to review the present design and engineering practices in noise attenuation.

3. To review the current status of personal hearing protection equipment, its maintenance and use.

4. To review the current status of audiometric testing programs.

5. To examine the basis of compensation for occupational hearing loss and the rehabilitation programs assisting those with occupationally induced hearing loss.

6. To make comprehensive recommendations to the council on the above points.

The task force made two decisions to delineate its scope. Since the minister requested a report on "industrial deafness", the other effects

* See page G.5.

of sound on the human body were not studied. The task force considered this another subject worthy of analysis, but did not comment further. In addition, the task force decided not to review or comment upon the regulation to control noise published by the Ministry of Labour in the *Ontario Gazette* in September 1978. This regulation is under study by the ministry and will deal with aspects of preventing noise-induced hearing loss.

The overlap between the regulation and the task force's terms of reference results in some of the same subject matter being considered. In the council's opinion, regulation of noise control is necessary and the process for regulating noise as a designated substance should be completed as quickly as possible..The council will deal separately with the ministry's proposal for a noise regulation when it is presented to the council for review.

This report will focus on matters of principle and policy in the areas of prevention, compensation and rehabilitation. The task force did not present its findings as an expert body on all aspects of noise-induced hearing loss. It reviewed the findings and recommendations of the Ontario Ministry of Health's Project Team Report on Occupational Noise (December 1974) and James Ham's Report of the Royal Commission on Health and Safety of Workers in Mines (1976) and was privy to a recent draft of the American Conference of Governmental Industrial Hygienists, "Noise Threshold Limit Documentation." Using the references in these reports, the council, through the task force, was able to review a vast and rapidly expanding literature on the many facets of sound and the prevention of noise-induced hearing loss.

The control of sound levels in industry is one of the most significant occupational health issues confronting society today. A review of the historical background on the recognition, evaluation and control of sound levels in industry and the prevention of noise-induced hearing loss explains in part why it is so difficult to estimate the number of employees at risk. Two major factors have changed to bring this occupational health problem to the forefront. The first change concerns attitudes toward noise-induced hearing loss. The second deals with society's growing understanding and awareness of the effects on human perception of different types and levels of sound combined with the duration of an individual's exposure. These factors have interacted within a social climate which increasingly stresses the importance of controlling risks to the health of employees.

Historically, workers in trades like boilermaking, mining and weaving accepted the fact they might lose a great deal of their hearing, although they did not understand the full import of deafness. As technology advanced, machinery became more powerful and, in many cases, louder. At the same time, the need for acute hearing in the communications and defence industries sparked the study of the relationship between the structure of sound and the human perception of sound. It was only after the second world war that the dose-response relationship between sound and loss of hearing began to be defined more scientifically. A review of the literature in the early 1950s shows the wide differences in instrumentation and related units of measurement and methods relating sound levels to effects on hearing levels. It is not surprising that preventive efforts in industry did not begin to take shape until the late 1950s. As the Ham Report notes, miners in the early 1960s were still forced to accept the possible loss of their hearing — it was part of the job.

Attitudes toward noise-induced hearing loss have changed in the past 20 years. People have realized that this type of permanent hearing loss is preventable, but incurable once it occurs. There is an increased emphasis on the maintenance of the individual's health, and labour unions have taken a leading role in noisy industries to convince their members and employers to reduce sound levels. The preventive programs adopted by many employers have become more effective as employees, especially young employees, have decided that they want to conserve their hearing. Loss of hearing is no longer an acceptable hazard of work.

At the same time, people have had an increased exposure to loud sounds during recreational activities. Realizing the potential effects of sound levels generated by their products, some manufacturers of snowmobiles and chain saws have improved design so that sound levels have now decreased. However, the proven effects of high sound levels from recreational activities are not great in comparison with occupational noise exposure. It is difficult to disassociate the different factors leading to a total dose received by a population. At present the occupational fraction of total exposure is several orders of magnitude greater than that attributable to recreational activities. In future, the potential effects of recreational noise should be watched carefully. The council's justification for this judgment is that the critical element is the dose (sound level and length of time) of high levels of sound to which one is exposed. Periodic short exposures to high sound levels is not thought to have a permanent effect on hearing. In examining causes of occupational hearing loss, the contribution of occupational, military, recreational and medical factors should be sought and evaluated. To illustrate this point, many older employees have experienced some loss of hearing because of their service during the second world war, compounded later by occupational noise exposure.

The human ear itself can influence the nature of noise-induced hearing loss. The cochlea of the inner ear is lined with hair cells which transform sound energy into nerve impulses. These cells respond to different sound frequencies and those cells sensitive to high frequency sound are the first to be damaged by excessive exposure to loud sound. In fact, the first manifestation of noise-induced hearing loss is loss of hearing in the high frequencies. Individuals also differ in their response to sound. Sound levels which damage some ears may not affect others. For policy purposes, this is significant because it is possible to identify the hypersensitive individuals at an early age by audiometric monitoring.[1] The results of these tests enable a physician to recommend to employer and employee a change of work environment where hearing conservation methods cannot help.

INFORMATION

There are only a few studies in the literature which attempt to relate noise exposure to hearing loss and their results vary widely. There are several reasons for this: lack of stable noise levels over a sufficient number of years in a given industry, confusion about the relative effects of steady state, interrupted or impact noise, lack of knowledge of individual noise exposure, lack of sufficient population with adequate hearing measurements, and others. The need for more information is clear and urgent.

The ability of the council to define the precise extent of the problem is limited by the above factors. More practical barriers exist. Some companies do not conduct audiometric programs to measure hearing. Those which do measure employee hearing do not always maintain records which can be compared among companies. In some instances, audiometric records are placed in an individual's file and are not available for an analysis of the status of hearing among company employees. These company records are not available for analysis at the provincial level where there is lack of overview of the state of hearing among employees. There is a concomitant lack of information on actual noise exposures of employees, even where audiometric testing is done. Personal sampling devices are not widely used. While the Ministry of Labour has had some authority to control sound levels at 90 dB(A) and above, it is not possible to obtain an overview of sound level trends by industry or occupation without extensive research because records are inadequate. Data on sound levels at 85 dB(A) are even less available since companies are not required by law to collect this information.

The lack of records and the method of maintaining records limit the assessment of the specific status of hearing loss and sound levels in Ontario. This is compounded by the varying attitudes toward hearing loss and other complicating factors. It is very difficult to obtain valid estimates without careful screening of the data linking personal exposure to sound with work histories, and audiometric records. The council realizes that linking these data elements gives rise to the administrative issue of ensuring the confidentiality of an individual's health records on the one hand, while not unduly inhibiting the development of scientific knowledge on the other. Obtaining better scientific understanding of the effects of sound on hearing is certainly a significant research priority. The cost to society of establishing an information network to produce such information should be considered since, according to some industries' estimates, it may be in excess of $100 per employee per year.[2] This is an example of why we should try to estimate the cost of preventing occupational hearing loss. Since an overall estimate of the total cost for Ontario is not available in the council's view, there is a great need for economic analysis based on actual Ontario evidence. The need for this information will become more apparent in the next section of the report.

In recent years, the scientific understanding of sound and its effects on the human ear has increased greatly, but many controversial issues remain from the standpoint of drafting regulations. A major problem exists concerning time dose relationships. Does doubling the intensity of sound double the risk of hearing loss? It is believed that within the range of 80-120 dB the harmful effect of noise is a result of the total quantity of sound energy received. Proponents of the equal energy principle argue that "the risk of injury depends on the total sound energy of the noise exposure, regardless of how the energy is distributed in time,"[3] whether that be an intense sound for a short period or a less intense sound for a longer period. Therefore, they believe that, if the intensity of a sound is doubled, then the exposure period should be halved. As a doubling a sound intensity is a 3 dB increase, (based on a logarithmic scale) this has given rise to the concept of loudness equivalent (L_{eq}) and tables based on it, i.e. if eight hours is safe at 90 dB, then four hours is safe at 93 dB or 16 hours at 87 dB. This 3 dB halving-doubling rule has been adopted in

Europe. In most of North America this concept has not been accepted because the equal energy rule is considered too conservative, not taking into account intermittent or impact noise; it may also not take into account the ability of the human ear to recover partially, when sound levels are less intense, from the effects of short intense noise exposure.[4] Instead, most North American jurisdictions have adopted a 5 dB trading relationship, i.e. if eight hours is safe at 90 dB, then four hours is safe at 95 dB and 16 hours at 85 dB.

It has been possible only recently to quantify personal noise exposure through the use of noise dosimeters, which are becoming more reliable since the introduction of micro-processors. As information becomes available from these measurements, it is probable that the relationship between sound levels and damage to hearing will have to be re-examined in the light of new data on the actual exposure of employees in the course of a work week. This more precise information may illuminate some of the hidden aspects of the effects of sound on hearing. The issues of the effects of impact noise and intermittent noise are still under study. There is almost no information on the effects of long-term noise exposure on employees working 12-hour shifts.

RECOMMENDATION ACOHOS 79-20/Minister's response p. 116 *

That, for the purposes of prevention, the Ministry of Labour periodically assess the appropriateness of the sound level standard adopted in Ontario and that there be established appropriate record linkage systems to collect local data relating actual individual sound exposures and audiometric monitoring results.

ESTIMATE OF EMPLOYEES AT RISK

The previous section explained the reasons for the weaknesses in the scientific understanding of the effects of sound on hearing. This uncertainty places a limit on the reliability of any analysis of the numbers of employees at risk, as well as the basis for any standard for the control of sound levels at work.

Assuming that sound levels affect the human ear in the same way in Ontario and other countries, international research may provide an estimate of the number of employees at risk. The Workmen's Compensation Board records also provide statistics which indicate historical trends in Ontario.

An estimate of the number of workers at risk due to continuous noise above 85 dB(A) can be made using figures extrapolated from the National Institute on Occupational Safety and Health's *National Occupational Hazard Survey*, combined with employment data from the U.S. Bureau of Labor Statistics.[5]

The American survey excluded certain industries, such as forestry and hard-rock mining, where many jobs expose workers to high sound levels. These are important exclusions from the point of view of Ontario. To compensate for this the council decided to use the upper limit of any estimate derived from the American survey. The data covers the non-agricultural work force.

The limitations of the survey data do not permit the council to make a definitive statement, but it believes the overall percerntage at risk to some noise above 85 dB(A) to be between 7 and 10% of the work force. Between 3 and 4% of the work force may be exposed to noise

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* Numbers referred to in the text appear in parentheses in the top right corner of the page.

above 85 dB(A) for more than 4 hours based on U.S. estimates. Another report indicates that about twice as many employees are exposed to 85 dB(A) as are exposed to 90 dB(A).[5]

Using the American estimates and assuming an employed work force of 4.3 million in Ontario, estimates of employees at risk to different levels of sound may be made. If sound levels by themselves are used then the following estimate would result:

- Since about 5% of the work force may be exposed to some sound above 90 dB(A) during a working day, there may be an estimated 215,000 workers at risk.

- Since 10% of the work force may be exposed to some sound above 85 dB(A) during a working day, there may be an estimated 430,000 workers at risk.

If sound levels plus exposure time are used, the following estimate could be made:

- Since 4% of the work force may be exposed to 85 dB(A) for more than four hours during a working day, there may be an estimated 172,000 workers at risk.

The implications of these estimates for policy planning and administration should be noted. By changing the legal exposure level from 90 to 85 dB(A), the number of workers brought under coverage would double to about 430,000. Taking into account intensity of sound and duration of exposure, some employees who are below a 90 dB(A) criterion using the 5 dB rule, would not be if the 3 dB rule were used to calculate equivalent exposure. By using the European method of calculation, i.e. a 3 dB halving and doubling factor, many more employees would be considered at risk.[7]

To place the size of the noise problem in perspective, the Ministry of Labour estimated at the end of 1977 that 19,577 persons were employed in the non-mining industries in various silica dust exposures. A further 15,000 were in dust-exposed jobs in the mining industry. A total of 30,392 analyses of biological samples was made for lead, mercury, fluoride, zinc, arsenic, cadmium, copper, phenol, nickel, manganese, thallium, and chromium.[8] The number of employees exposed to noise above 90 dB(A) is larger than the number exposed to any one of these other substances. The council uses these statistics to illustrate the extent of the "noise problem", while realizing that some of the agents referred to may pose a far more potent risk to human health than the long-term effects of sound.

Sound levels vary according to industry. Typical of high noise industries in North America are:

- mining

- manufacturing:
  - food and kindred products
  - paper and allied products
  - printing and publishing
  - textiles

- rubber and plastic products
- primary metal products
- fabricated metal products

- transportation equipment.

Adapting this to Ontario, the council would add forestry and some areas of the construction industry. The sound levels within these industries are quite high, with many areas having sound levels above 90 dB(A). Appendix I provides illustrations of the typical sound levels of machinery and equipment in some of these industries.

The council also examined Workmen's Compensation Board statistics on compensation cases claimed.[9] Mining and non-mining industries contributed almost equally to the total number of claims to the board for compensation as indicated in Table I. Twenty-one rating groups accounted for 87% of the non-mining claims filed. These are summarized in Table 2. The industries are much the same as those identified as high-risk industries from American sources. They are also the economic backbone of the province, especially when the mining industry is taken into account. Other characteristics of importance are that:

- The mean age of those granted disability awards in the period 1949-78 was 57 years (Diagram 1).

- The mean percentage award for permanent disability was 7.0% from 1949 to 1977, and between 1973 and 1978 the percentage disability has dropped steadily from 9 to 5.5.

- The average total value medical aid and capitalized pension costs for permanent disability settlements has risen in 1978 to $6,448.20 (which gives rise to an average lifetime payout per award of approximately $16,000).

- According to board data, claims submitted and adjudicated have dropped from 1,874 in 1977 to 1,215 in 1978, and pensions awarded have decreased from 1,303 in 1977 to 967 in 1978.[10]

The council does not believe that the decreases in claims and pensions should be taken as a sign that the backlog of claims has been cleared up. It suspects that there is a large reservoir of cases which would be uncovered among many companies, regardless of size, which have not instituted hearing conservation programs. This is particularly emphasized by the comparatively small number of awards made in non-mining industries which have a much larger number of workers to draw from. The council notes that studies indicate 5% of the working population may suffer a hearing impairment* greater than 25 dB(A) in the speech frequencies (the point at which hearing handicap is quite evident), and 2% may have a loss greater than 35 dB(A). What is more disturbing is that as many as 30% of the work force may have a significant loss of hearing in the high frequencies.[11] Any concerted effort to extend the scope of preventive programs will identify this reservoir, resulting in a further surge in claims for compensation. Depending on the nature of the program thrust, the surge could last from five to seven years.

If an 85 dB(A) standard is adopted, then more than twice the number of employees will be covered than is the case under the 90 dB(A) standard under the Industrial Health and Safety Regulations of the Occupational Health and Safety Act. The shift to 85 dB(A) would also mean that the sound intensity would be reduced by at least one half. These are sizeable, indeed significant, effects, and the council would like to review whether risk reduction accompanying such a shift would be at a similar scale.

The international standard ISO 1999 gives some idea of the subjects at risk to hearing impairment* at different sound levels. It indicates that a loudness equivalent of 85 dB(A) reduced the risk of impairment by 10% compared to a 90 dB(A) loudness equivalent and that the 85 dB(A) level will protect about 92% of those exposed eight hours per day, 40 hours a week, for 30 years.[12]

North American studies based on time-weighted averages using a 5 dB halving and doubling time suggest that exposure to 90 dB(A) for eight hours, 40 hours a week for 30 years may result in 18% of the population at risk suffering a hearing loss of 25 dB in the 500, 1000, and 2000 Hz ranges.[13] In simple terms, an 85 dB(A) exposure level protects about 92% of those at risk while a 90 dB(A) exposure level protects about 82 - 85%. Approximately 10% more are protected by shifting from a 90 to an 85 dB(A) standard. However, even these estimates should be viewed with caution because of differences in the selection of subjects included in the studies, methods used to measure hearing of the subjects, difficulty in finding subjects exposed to 85 dB(A) steady state noise, and training of technicians.[14]

Table 1

Claims Set up by Five Year Periods

	Schedule I Companies			*Schedule II Companies*	*Totals I & II*
	A	*B*		*C*	
	Mining	*Non-Mining*	*Total*		*A & B & C*
1949-1953	2	2	4	1	5
1954-1958	10	18	28	3	31
1959-1963	31	151	182	3	185
1964-1968	224	387	611	17	628
1969-1973	794	901	1,695	49	1,744
1974-1978	4,174	3,731	7,905	182	8,087
Total	5,235	5,190	10,425	255	10,680

Source: Workmen's Compensation Board, Industrial Noise Deafness Report, Claims Reported by Year Claim Set Up and Rate Number, January 1980, Table 2.

Table 2

Non-Mining Rating Groups of Interest 1949-1978—(Schedule 1)*

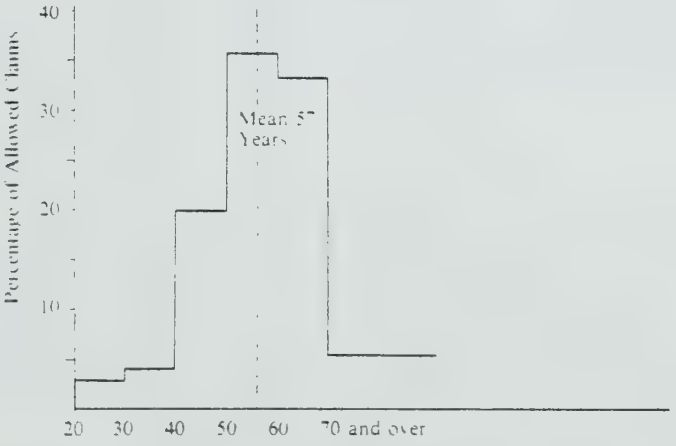
Rate	*Industry*	*Total Claims*
023	Forestry and logging	641
162	Steelmaking	1847
170, 180, 204 & 212	Metal casting, forming	134
246	Metal product manufacturing and repair	688
255 & 264	Bolts, cables, wires, small metal machinery	120
288	Electrical appliances and apparatus	144
298	Agricultural implements and machinery	178
306	Automobiles	261
310, 315 & 331	Airplanes, autobodies, car shops	117
349	Petroleum products	88
405	Chemical products	45
555	Textiles	66
753	Excavating	50
854	Construction	93
864	Installation and repair metal products (e.g. furnaces)	47
Total		4519

Source: W.C.B., Industrial Noise Deafness Report, Claims Reported by Year Set Up and Rate Number 1949-1978, January, 1980, Table 2.

*These rating groups account for 87% of the claims

Diagram I
All Industries Schedules I & II

Age Distribution of Claims for Hearing Loss First Allowed in Period 1949-1978—(Includes Medical Aid Awards)



Source: Workmen's Compensation Board, Industrial Noise Deafness Report, Allowed Claims by Age and Year Claim First Allowed, January, 1980, Table 8

Most of these studies have not included analysis of sound on the perception of higher frequencies.[15] A recent report compared hearing levels of 155 males and 193 females exposed to sound levels ranging from 82 to 92 dB(A) for at least three years with a median duration of approximately 15 years and 96 males and 132 females with occupational sound exposure not exceeding 75 dB(A). The report found that:

> Differences between females exposed to 82 to 92 dB(A) and their controls were small and were not statistically significant. Differences between males exposed to 82 to 92 dB(A) and their controls were small and were not significant at 500, 1000, and 2000 Hz. Levels in the noise-exposed group (in males) significantly exceeding those in the control group at 3000, 4000 and 6000 Hz by approximately 6 to 9 dB. At 8000 Hz, differences again became not significant.[16]

The economic implications of adopting a sound level of 85 dB(A) must be considered. In the United States the average capital cost of achieving a 90 dB(A) standard has been estimated to be $1,005 per worker five years after the standard takes effect. The estimated additional average capital costs of achieving an 85 dB(A) standard five years after the standard is achieved, dropped from $1,430 to $625 per worker after more refined analytical techniques were applied to a more representative data base. This serves to highlight the need for care in interpreting and extrapolating these estimates to Ontario. Estimates of capital costs in some industries like textiles and primary metals are considerably higher than the average capital costs. These same studies estimated annual costs for measuring sound levels to be $12 per worker and audiometric tests to be $20 per worker.[17] Industry argued that these costs were serious under-estimates of the true costs of meeting an 85 dB(A) standard, taking into account such factors as training, supervision, and research and development. Priced in 1979 dollars and taking these comments into account, costs for achieving an 85 dB(A) standard would be significantly more than a 90 dB(A) standard. As the number of employees exposed to 85 dB(A) is approximately double that exposed to 90 dB(A), the total cost of adopting an 85 dB(A) workplace standard could at least be double that of adopting a 90 dB(A) standard.

PREVENTION

Sound and its affect on hearing is one of the most widespread occupational health problems in Ontario industry. The preventive techniques available to industry and government to control sound levels at work are well known.[18] The council does not intend to comment in detail on the efficacy of each procedure. Instead, it will focus on the relationship between voluntary initiative and legal requirement and will comment upon significant issues which require special attention.

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*See glossary for definition

Government Regulation

There are several components of a comprehensive noise control/hearing conservation program. The sound levels must be measured, the level of hearing of workers must be monitored, and different noise-control techniques must be adopted to reduce noise to a predetermined level. If this level cannot be achieved, personal protective equipment must be provided and used. The most difficult question facing the council is: At what sound level should these activities be required by regulation? The evidence reviewed on estimates of those at risk, the effects of different sound levels, and the costs involved to employers, employees, and society indicate that there are convincing reasons for a staged sequence of required action depending upon the sound level encountered and the duration of exposure.

The protection of hearing depends upon the identification of potentially hazardous sound levels and the effects of those levels on the employee at risk. To be effective, the monitoring of sound levels should begin in workplaces with sound levels of 80 dB(A) or more. The council will not comment upon the specific numbers of measurements which should be taken. In principle, it believes that the measurements should be taken when there is reason to believe circumstances have changed, leading to an increase in sound levels which requires certain action. The monitoring of employees' hearing should commence when they are exposed to 85 dB(A) for four or more hours. There is sufficient evidence to argue that some employees exposed to this level of sound may be at risk and should be identified so that corrective action can be taken.

The council also believes employers should be required to issue personal hearing protection to employees exposed to 85 dB(A) or more. However, realizing that employees may not perceive sound levels under 90 dB(A) as being hazardous, the use of personal protective equipment in workplaces having sound levels between 85 and 89 dB(A) should be voluntary. In these circumstances its use should be encouraged by education programs, but it should be mandatory in all workplaces with employees exposed to 90 dB(A). This practice exists in Germany.[19] There is no point in undermining the credibility of hearing conservation programs by requiring the use of personal protective equipment in circumstances which do not place an employee at great risk and, more importantly, which the employee believes does not place him at risk. Furthermore, the council argues that use of protective equipment should not be linked to a duration of exposure. For ease of administrating the program in companies, all people entering work areas where signs indicate the mandatory use of hearing protection must wear the devices while in the area. Companies should be required to reduce sound levels to 90 dB(A) by whatever means available.

To achieve a legal control standard, the council believes companies should consider every option available and develop a program best suited to conditions. The basis for this principle rests on the difficulties encountered in attempting to impose a single, uniform solution to a very complex problem. For instance, engineering controls are regarded as the most effective means to control sound levels. The council has examined reports on the feasibility of lowering sound levels in

machinery and equipment where metal strikes metal. This is a most difficult task which still requires considerable research.[26] The first line of defence to protect workmen from a noise hazard is to engineer out the existing problem, where feasible. This entails considering a series of alternatives, including eliminating the noise source, isolating the noise source or isolating the workers in soundproof booths or other soundproof structures. Different work practices may also be considered along with engineering controls. Where work practices or administrative control are mainly used, the industry is not relieved of the obligation of researching and applying new technology to render engineering controls feasible.

RECOMMENDATION ACOHOS 79-21/Minister's response p. 118

That the Ministry of Labour should sponsor ongoing research on the reduction of sound levels in machinery, and equipment where metal strikes metal.

The council is convinced that in the short term the most effective legal control standard for all industry is 90 dB(A) with no exposure permitted above 115 dB(A). It also believes the evidence on the degree of risk at 85 dB(A) does not warrant a legal standard to be set at this level of protection. Even NIOSH recommended a cautious approach to implementing an 85 dB(A) standard, especially where it applies to existing equipment.[27] It is particularly important to realize that much of the problem of hearing loss could be prevented if 90 dB(A) sound levels were achieved. Where the 90 dB(A) standard cannot be achieved by other methods, personal protective equipment must be supplied and worn.

RECOMMENDATION ACOHOS 79-22/Minister's response p. 119

That the Ministry of Labour adopt a regulation requiring:

- periodic measurement of sound in workplaces with 80 dB(A) or more;
- audiometric testing of employees exposed to four or more hours of sound at 85 dB(A) or more;
- employers to provide personal hearing protection devices where employees are exposed to 85 dB(A) or more;
- employers to reduce sound levels to 90 dB(A) by whatever means possible and, where this cannot be achieved, to require employees to wear personal protective hearing devices.

RECOMMENDATION ACOHOS 79-23/Minister's response p. 120

That the Ministry of Labour periodically assess the scientific and economic justifications for adopting a standard requiring employers to reduce sound to 85 dB(A).

Voluntary Initiative

The preventive procedure outlined in recommendation 79-22 serves as a minimum base for a program to control noise and preserve hearing. The council realizes that the achievement of this and more advanced procedures depends upon the initiative of management and labour. Voluntary initiative is required if employees are to be protected. The council believes companies should be encouraged to institute hearing conservation programs in all workplaces with sound levels greater than 85 dB(A). Taking into account the legally required procedures, the council believes companies should voluntarily develop a written policy which would outline the procedures to be instituted, namely:

- specifying sound levels as low as reasonably achievable when purchasing machinery or equipment;
- engineering controls to reduce noise to 85 dB(A) wherever possible;
- measuring the sound levels in the workplace;
- audiometric screening for employees exposed for four or more hours to 85 dB(A) or more;
- education; and
- provision of personal protective equipment.

All workplaces with employees exposed to sound levels at 90 dB(A) should include in their written policy in addition to the above, direction for:

- annual audiograms;
- engineering controls;
- mandatory use of personal protective equipment, where other types of controls fail; and
- administrative and work practice controls.

The policy giving direction to the hearing conservation program and other records relating to it should be available to the Ministry of Labour for review.

Personal protective hearing devices by themselves are not a satisfactory approach to prevention. Research indicates that these devices frequently may not give the attenuation from sound that is advertised.[22] The critical factor with personal protective equipment is how the device is actually worn and its suitability to the individual and the job. Therefore, it is important that employees be given the opportunity to participate in selecting the device and be properly instructed in its maintenance and use. As a result of discussions with representatives from management and labour, it is obvious that training and maintenance programs in this area need to be improved. In keeping with the spirit of the Occupational Health and Safety Act, 1978. The council recommends:

RECOMMENDATION ACOHOS 79-24/Minister's response p. 121

> That employees be given the opportunity to participate in a hearing conservation program from the planning stages and, within approved types of equipment, employees be given a choice of the type of personal hearing protection equipment to be used on the job.

As exposure time to sound is a critical issue, the problem of employees working 12-hour shifts, or double shifts, must be examined. All the work which has been done on examining the relationship between sound levels and hearing loss has used employees with a typical eight-hour shift. Even with overtime, this exposure does not compare to the employee on 12-hour shifts who may not be off work for a long enough period to recover from the effects of his previous day's exposure. Assuming that the hazardous sound cannot be engineered out, the companies should consider adopting work practices enabling employees on long shifts with sound levels at or above 90 dB(A) sufficient time to recover. The council also believes it is vital that more research be conducted on the effect of sound on workers' hearing while on long shifts.

RECOMMENDATION ACOHOS 79-25/Minister's response p. 117

> That the Ministry of Labour sponsor research on the actual individual noise exposure experienced by employees and, in particular, examine the actual sound levels experienced by employees on long work shifts and the effects of these levels on hearing.

In the long term, the most effective means to reduce sound levels at work is through equipment design and manufacture. Once again, voluntary industrial initiative has the greatest role to play in this area. For instance, company purchase specifications should state the sound level required at time of installation and delivery. This target for installed new equipment should be as low as reasonably achievable. This practice presently varies among companies, many of which do insist on specific sound levels in new equipment. In certain circumstances where heavy forge hammers are used and in foundries, correct installation of equipment is necessary to meet optimum performance standards. However, only a preventive maintenance program can control the rising sound levels caused by wear and tear in these environmentally designed machines. The importance of the issue of design is underlined by a proposal to establish under the National Research Council an associate committee concerned with the general problem of machinery noise reduction and in particular with:

> Reduction of the noise radiated by newly manufactured Canadian machines/products so that competitive noise and cost performance is achieved, consistent with an acceptable noise exposure for the user.[53]

This enterprise should be encouraged, especially as it would assist small establishments which may not be in a position or be aware of the need to consider setting sound levels in purchase specifications for new equipment.

In conjunction with equipment design and preventive maintenance, the layout of machinery and equipment is a critical factor in controlling sound levels. This is true for office buildings where noise may be more of a nuisance than a risk to health. Whenever plant layout is changed to accommodate new equipment or a new work flow, an opportunity arises to consider the acoustical features of the workplace. The issue of the existing plant layout should also be addressed. Since the Ministry of Labour is responsible for reviewing plans for new industrial establishments and alterations to existing facilities, it seems logical that the acoustical aspects of buildings be considered.

RECOMMENDATION ACOHOS 79-26/Minister's response p. 118

That competent authorities work with manufacturers of equipment and machinery to reduce sound levels on new products, and that the Ministry of Labour along with other competent authorities work with the federal government to seek labelling provisions requiring machinery and equipment to have sound levels marked.

RECOMMENDATION ACOHOS 79-27/Minister's response p. 122

That the Ministry of Labour encourage employers to adopt preventive maintenance programs to control sound levels.

RECOMMENDATION ACOHOS 79-28/Minister's response p. 122

That the Ministry of Labour consider the feasibility of including a review of acoustical features when examining plans for new or changes in existing workplaces.

In determining the feasibility of recommendation 79-28, the ministry should consider whether such a practice would hinder construction of new buildings. It is not the council's intention that the review of plans should result in delay in construction.

Prevention programs vary by size of company and resources available. While the council's Task Force on Occupational Hearing Loss has not toured the province and consulted with many employers and employees, it has met with a number of representatives from unions and industry. As a result of these deliberations the council believes noise control programs are weakest among small companies which are lacking engineering expertise and are conscious of the potential costs involved in reducing the sound level of their machinery. The council's Advisory Memorandum 79-1 on small establishments contains several recommendations directed at overcoming this problem and suggests a subsidy program for small establishment health and safety programs. In addition, it has been alleged that companies may not institute audiometric testing programs because they may uncover employees with hearing loss, leading to a compensation claim against the company. This could create a real psychological barrier to the expansion of an effective audiometric testing program in the province. The Workmen's Compensation Board's Second Injury and Enhancement Fund was created for dealing with aspects of this

problem and companies should be aware of its existence as part of any promotional literature on prevention of hearing loss published by the Ministry of Labour, or the accident prevention associations.

AUDIOMETRY

The purpose of audiometric screening in a hearing conservation program is to serve as a biological monitor on the effectiveness of control procedures and to identify those individuals who require diagnostic tests to pinpoint the extent and possible cause of the hearing loss. The council realizes that audiometric services in conjunction with sound monitoring may be expensive. However, audiograms should be done in several specific instances:

- Initial audiometric examinations within the first three months of employment for all employees who might be exposed to 85 dB(A) for four or more hours per day.

- An annual audiogram for those exposed to 85 dB(A) for four or more hours per day.

The council considered other proposals which would require a different frequency of audiometric tests for employees exposed to different sound levels. These were rejected because they were administratively complex and too expensive.

RECOMMENDATION ACOHOS 79-29/Minister's response p. 120

> That the Ministry of Labour require employers to provide initial screening audiograms within the first three months of employment for all employees exposed to 85 dB(A), or more, for four or more hours per day;
>
> That the Ministry of Labour require employers to provide initial screening audiograms to all employees exposed to 85 dB(A), or more, for four or more hours per day; and
>
> That the Ministry of Labour review and modify this policy if results of the program indicate there is a more reasonable pattern for administering audiometric tests.

There is a significant difference in the skills, and therefore the education, necessary to conduct a screening audiogram compared with a diagnostic audiogram. A screening audiogram is simply a pure tone test of a person's hearing in several frequencies, given by a properly trained technician. This test is conducted in a booth which should meet government guidelines, using equipment which should be regularly calibrated, in a room which should have a low ambient sound level. These factors are all considered in the Ministry of Health's guidelines for audiometric testing.[24] A screening audiogram does not provide the necessary information for establishing or refuting a compensation claim, although the specialists used by the Workmen's Compensation Board will review whatever information in a claimant's file they believe is useful. However, the council wishes to emphasize that for purposes

of its report the screening audiogram is sufficient to monitor the effectiveness of a hearing conservation program, and to identify those individuals whose hearing levels are changing. Such individuals should be referred to specialists for more thorough diagnoses.[25]

In reviewing the existing practice of audiometric testing with industry and several private hearing testing companies, certain crucial issues emerged. These concern:

- the training of audiometric technicians;
- the shortage of audiologists and technicians;
- the lack of professional standards for audiometric technicians; and
- the need to ensure that testing equipment is properly calibrated and that the testing environment meets proper guidelines.

The council is aware of and accepts the guidelines for audiometric testing developed by the Ministry of Health and Ministry of Labour. It believes these technical matters are well in hand, and that the effectiveness of any new regulation requiring employers to provide audiometric tests to employees exposed to 85 dB(A) or more for four or more hours per day depends upon the quality and availability of audiometric technicians.

At present the University of Toronto, Queen's University and Lakehead University are offering short courses in audiometry. The University of Toronto's course is the oldest and the demand for the 3½ day course last year was such that an additional session was scheduled. The programs at Queen's and Lakehead have been established in the last year and are of similar duration to that at Toronto. With these courses, people have gone out to act as audiometric technicians. As long as they work under medical supervision or under an audiologist, this type of training is probably adequate. The problem in expanding these training programs is a shortage of instructors. In other cases where the personnel are available, they may lack the time or desire to participate. In some cases, because of the distribution of otolaryngologists and audiologists across the province, they may not be located close enough to serve a local educational program. The council believes that as long as the instructors are available and local communities will support the effort by supplying students, there is no reason why community colleges could not offer this course through continuing education departments. It would seem logical for those community colleges which wished to set up such a course to consult with the University of Toronto or other established programs and gain from their experience. Cooperative arrangements between the community colleges and the universities in this discipline would be useful.

The demand for audiometric technician training programs should expand in the future. However, it is difficult to estimate this growth or total numbers.[26] Those who do complete a course enter a business which is paramedical in nature, but one which lacks arrangements for ensuring the maintenance of professional standards. A possible method for resolving this problem is for the Ministry of Labour, in consultation with those responsible for the training programs, to set out its requirements for minimally acceptable audiometric tests and only accept those submitted from graduates of approved training programs. Another option touches upon the sensitive issue of professional control by licensure or certification. The council believes

this option should not be considered until the Professional Organizations Committee to the Attorney General publishes its report. At such time, the principles for deciding on what bases to regulate an occupation should be reviewed, as they apply to audiologists as well as to audiometric technicians. Nonetheless, the council believes that in considering this option, the following factors should be taken into account:

- The need to regulate audiologists and or audiometric technicians at all, considering the probability of harming an individual.
- The ministry which should retain control.
- Whether audiologists and technicians should be licensed directly by a ministry, or if they should be licensed or certified under the Health Disciplines Act, 1974.

These questions can only be answered with considerably more research than has been conducted and only after a policy on the control of professionals is reviewed by the government. In the meantime, the council recommends:

RECOMMENDATION ACOHOS-30/Minister's response p. 120

> That the Ministry of Labour work with the Ministry of Colleges and Universities in developing a standardized audiometric technician training program across the province.

The council also endorses the recommendation of the Royal Commission on the Health and Safety of Workers in Mines, which suggested:

> That the Occupational Health and Safety Branch regularly inspect all audiometric testing facilities not under the supervision of a designated medical specialist, and that any designated medical specialist be required to certify biennially in writing that the facilities under his supervision conform to the minimum standards of the Ministry of Health as then current.[27]

RECOMMENDATION ACOHOS-31/Minister's response p. 121

> That the Ministry of Labour ensure audiometric testing programs be carried out under appropriate professional supervision; and
>
> That the Ministry of Labour establish a code of minimum practice, setting out minimum standards for (a) calibrating audiometric testing equipment, and (b) the permissible ambient sound level within a testing booth.

The issues of records and access to the results of audiometric tests pose particular problems, especially where a company does not have a physician. Taking the latter point, there are instances when audiometric test results are returned to personnel directors or other management people who are not able to interpret the results or advise workers in a professionally competent manner. While management must be

informed if its employees are suffering a loss of hearing attributable to the workplace so that they can take corrective action, they should have this information in a form which protects the individual, since an audiogram is a medical record and not a personnel record. The uses to which the information on hearing loss can be put are more complex than in similar areas, such as information on an individual's exposure to lead or vinyl chloride monomer. Referring to its advice on the confidentiality of medical records submitted to the Minister of Labour, the council believes that employees should be informed and counselled by a professional on the meaning of the results of the audiometric tests, and the employer should be informed of the results of an individual's audiogram, especially when it appears that a noise control hearing conservation program is not being effectively implemented.

The issue of confidentiality presents a series of problems: Whose record is the audiogram, how long should it be kept and where should it be housed? The council believes that since a screening audiogram primarily serves a preventive purpose, it should be retained at the company level under medical supervision. The records should be retained by the company for the same period of time it retains its other employee records. The council realizes that after such time a suitable mechanism must be found to store such records, and acknowledges that this is one example of a wider issue concerning the development of information necessary for monitoring the effectiveness of health and hygiene programs. The council is awaiting the report of its Task Force on Information to present recommendations on this matter.

Finally, the council realizes that a mandatory audiometric screening program will result in an increased demand for diagnostic hearing tests. Many of these diagnostic tests will be for purposes of establishing a basis for compensation for occupational hearing loss. On the basis of past experience with the large surge of claims for pensions for noise-induced hearing loss evaluated by medical specialists, the council believes the present supply of medical specialists should be able to meet the expected demand for their services in the future. The council dismisses the issue of the supply of medical specialists acting as a barrier to implementing any policy or program for a more extensive audiometric screening program in the province.

COMPENSATION

The Basis of Compensation: Present Policy

Hearing loss from exposure to occupational noise was first recognized in North America as a compensable disease as a result of a decision by a New York court in 1944. In Ontario it became compensable in 1947. The council understands that in 1947 a person could not receive compensation for noise-induced hearing loss until six months after retirement. Until the end of 1973, a person could not receive a pension for hearing loss for which he was eligible until he removed himself from work in noise exposure. The Ham Commission noted that no special program of rehabilitation was offered to assist such people.[28] On January 1, 1974, the Workmen's Compensation Act was modified so that administrative compensation practices for compensation for hearing loss became the same as that for accidental injuries. People

with hearing loss became eligible on that date for disability awards while continuing to work in noise exposure. This explains why there was a surge in compensation cases for hearing loss since previously a large number of people elected to remain at their jobs in noise rather than file a claim for compensation and change jobs or employment.

The trend in compensation rules in other North American jurisdictions has been to compensate for handicap and not solely for disability. *Disability* is defined as an inability to remain employed at full wages. *Handicap* is a disadvantage imposed by impairment such that one's ability to participate in the activities of daily living are restricted. An *impairment* is a change for the worse outside the normal range.[29] A review of present of present Ontario guidelines for establishing the basis of compensation indicates that Ontario also compensates for hearing handicap.

In Ontario, the policy directing the administrative practice for adjudicating noise-induced hearing loss and tinnitus claims is set out in the Workmen's Compensation Board guidelines. Several criteria are required to be met before a claim can be accepted. The guidelines cover rules for eligibility for medical aid payments as well as permanent disability pensions for hearing loss.

Medical Aid

Based on medical advice, medical aid claims may be favourably accepted when all the following factors apply:

1. A clear and adequate history of five or more years of exposure to hazardous noise, 90 dB(A) for eight hours per day, or equivalent. Sound levels in excess of 90 dB(A) will reduce the five or more years exposure requirement.

2. Known frequency and type of exposure.

3. The average of the four speech frequency levels of 500, 1000, 2000, and 3000 Hz in the American National Standards Institute or International Standards Organization audiograms is 25 dB in each ear.

4. Since industrial susceptibility to noise varies, claims not meeting the above criteria may be judged on their own merit, having regard to the nature of the occupation, the extent of exposure, and other factors peculiar to the industrial case. The benefit of reasonable doubt applies.

Pensions

Entitlement to a permanent disability pension is established when all these factors apply:

1. The average of the four speech frequency levels of 500, 1000, 2000, and 3000 Hz in the ANSI or ISO audiograms is 35 dB in each ear.

2. 0.5 decibel for each year that the age exceeds 60 is subtracted to allow for the normal loss of hearing from aging (presbycusis).

The hearing loss in decibels is converted into percentage of disability in accordance with the following schedule which grants a pension of 30% for total deafness, except when caused by traumatic accident:

Partial hearing loss where both ears are affected:

dB hearing loss	Percent of disability
In single ear 35 dB ANSI/ISO	.4
In single ear 40 dB ANSI/ISO	.7
In single ear 45 dB ANSI/ISO	1.0
In single ear 50 dB ANSI/ISO	1.4
In single ear 55 dB ANSI/ISO	1.8
In single ear 60 dB ANSI/ISO	2.3
In single ear 65 dB ANSI/ISO	2.8
In single ear 70 dB ANSI/ISO	3.4
In single ear 75 dB ANSI/ISO	4.0
In single ear 80 dB ANSI/ISO	5.0

Note: In bilateral deafness the poorer ear is rated according to the above scale; the better ear according to the scale multiplied by five. The sum of the two gives the combined rating.

In applying these rules, the board policy states that the level of rating is not influenced by any improvement in hearing attained through the use of a hearing aid, and permanent disability awards are evaluated on a percentage ratio of Ontario industrial exposure to total exposure. In addition, where there is no pre-employment audiogram available, the board will charge the last Ontario-exposure employer for the claim in proportion to the ratio of the years at risk with an employer to total Ontario-exposure employment. The balance is charged to the Second Injury and Enhancement Fund on the assumption that prior noise exposure employment has caused some pre-existing hearing loss.[30] The board also sets out in the same policy rules for adjudicating ringing in the ears caused by occupational noise exposure.[3]

The Basis of Compensation: Future Issues

The policy of the Workmen's Compensation Board regarding occupational noise-induced hearing loss is certainly in keeping with the more enlightened practices in North America.[32] Nonetheless, the council is concerned about several issues which it will identify, but will not offer comprehensive advice. It takes this position because it feels limited by its terms of reference and the complexity of the matter. It is a subject worthy of separate, detailed analysis.

The council believes the basis of compensation for noise-induced hearing loss should be reviewed. Hearing handicap begins at 20 dB loss and by 25 dB is noticeable so that people suffering this degree of hearing loss have difficulty understanding one voice in many. They have difficulty conversing among groups. Questions have been raised about the equity of the policy. A person is compensated for an amputated finger or loss of an eye. A person claiming for hearing loss must wait until a fair portion of his hearing has been permanently lost

before even being eligible for a permanent disability pension. The council wonders whether these practices are fair, taking into account that impairment begins long before a 35 dB hearing loss. All these questions are related to the purpose of compensation. Should the board compensate solely for loss of earnings, or should it take into account other factors related to the degree of damage the work environment may inflict on an individual? It is far simpler to answer these questions when traumatic injury, including traumatic loss of hearing, is concerned than when considering the effects of long term exposure to chemical, physical, or biological agents. The council has three more specific issues which should be consider in any review of the basis of compensation for hearing loss. They are:

- The maximum limit of 30% total body disability for total chronic hearing loss;
- the rating scale used to determine the percentage of disability;
- the criterion of 35 dB hearing loss used to determine a claimant's eligibility for a pension for noise-induced hearing loss.

The council questions whether the 30% maximum placed on permanent disability pensions is fair to those who are deaf or almost deaf. It is aware that a blind person receives a pension valued at the maximum permissible. In present terms a blind person whose earnings were $16,200 and who is eligible for a permanent disability award would receive a pension of $12,150. Another person with the same earnings who became deaf through chronic exposure to noise and was eligible for a pension would receive $3,645. Yet it is just as difficult for the hard of hearing and the deaf to obtain employment as it is for the blind. When hearing is so poor that a shout is heard as a whisper — at a hearing level of 60-80 dB — most jobs are unattainable, since instruction by employers would be extremely difficult and communication with fellow employees almost impossible. In such circumstances those with severe hearing loss may be forced to find jobs at lower rates of pay in conditions which are less than pleasant. For these reasons the handicap and disability of a person with a severe hearing loss equates with those of the blind, since the same occupational constraints apply. Thus, it is incomprehensible that those almost deaf should be rated at 30% total body disability for chronic hearing loss. From 1949 to 1976 there have been only 20 cases of 30% permanent disability at first award. There are under 100 such disabled pensioners in all. Taking these small numbers into account, it can be argued that it would be fair to adjust the rating scale used to calculate the percentage of hearing loss for pensions. It might be feasible to give greater weight to severe chronic hearing loss in the rating scale and thereby to equate deafness with total disability.[33]

The final issue for consideration is the criterion of a 35 dB hearing loss to qualify for a pension. It is the council's understanding that the 35 dB limit is a result of historical accident and administrative decision rather than scientific fact. Indeed, scientific evidence suggests reason for change.

About 1950 Ontario decided to compensate hearing loss at 25 dB using equipment calibrated according to the American Standards Association. This was in keeping with North American practice. Some

time later, the United States decided to use the International Organization for Standardization (ISO) calibration and retained the 25 dB criterion (ISO) for awarding pensions. Ontario recalibrated its equipment based on ISO and in so doing converted its pension criterion to 35 dB using AAOO's three-frequency average. Compensation schemes in the United States were introduced after the conversion to the ISO guide and compensated hearing loss at 25 dB (ISO). Ontario has never changed its 35 dB criterion. If the board's policy is to compensate for handicap, as it appears to be, then consideration should be given to begin awarding pensions at least at a 25 dB level where hearing handicap is well established. The cost implications of this proposal require careful consideration, but the council believes a lower criterion could serve to act as a further incentive to industry to emphasize prevention and protection programs.

This practice has recently been confirmed by the American Academy of Otolaryngology and the American Council of Otolaryngology who revised their formula for determining hearing handicap. They maintained the 25 dB criterion, but added a fourth frequency, 3000 Hz, in assessing hearing loss in each ear. Previously only the 500, 1000 and 2000 Hz frequencies were used.[34] Ontario added the 3000 Hz frequency some years ago, but still has not adjusted its pension criterion to 25 dB. The council believes there is good reason to seek a thorough review of the basis of compensation, and although it is not charged with this responsibility, it feels impelled by the evidence to bring the matter forward. It believes a separate committee should be established to investigate and report to the Minister of Labour and the Workmen's Compensation Board. To avoid any allegation of a conflict of interest the council does not believe that employees of the board should serve as committee members. Because of the complex nature of the subject and in recognition of the expertise of the board's staff, the council believes there is a significant role to be played by them in providing advice and support to the committee.

RECOMMENDATION ACOHOS 79-32/Minister's response p. 123

That the Minister of Labour consult with the Workmen's Compensation Board to consider appointing an independent committee of experts to investigate and make recommendations to the minister and the board on the basis of compensation for noise-induced hearing loss and, in so doing examine:

- the maximum limit of 30% total body disability for total chronic hearing loss;
- the rating scale used to determine the percentage of disability; and
- the criterion of 35 dB hearing loss used to determine a claimant's eligibility for a pension for noise-induced hearing loss.

RECOMMENDATION ACOHOS 79-33/Minister's response p. 123

That the Minister of Labour ask the Workmen's Compensation Board to consider adjusting the disability rating for those with a 60 dB or greater binaural hearing loss on an interim basis.

The Workmen's Compensation Board relies upon existing medical expertise to provide the necessary diagnostic evaluation of claims for hearing loss. The council believes that the claimant, industry and the board itself are best served by continuing this practice.

Audiological laboratories serve the community and occupationally related cases are a small fraction of the total case load. Young children and the aged are two large groups which take up a good deal of time and attention. Diagnostic evaluations for noise-induced hearing loss take about twice the time as screening audiograms, and audiological laboratories cannot afford to concentrate on this aspect of hearing assessment. Indeed, hospital audiological laboratories specializing in occupationally related diagnostic work suffer a loss of income and may even "go broke". The fee*, which is paid by the WCB covers an inadequate portion of the costs of operating a laboratory.

The above issues are relevant to all aspects of this report. They present real and potential barriers to providing effective and preventive audiological programs, as well as accessible and equitable compensation and rehabilitation. The council could argue for a straightforward fee increase to create an incentive for the entrepreneur, but does not believe it has a mandate in this area. It does, however, recommend:

RECOMMENDATION ACOHOS 79-34/Minister's response p. 123

> That the Minister of Labour in consultation with the Workmen's Compensation Board and other appropriate government ministries develop and implement programs to ensure the availability of regional audiological facilities which are of a sufficiently high standard to allow effective and efficient adjudication of noise-induced hearing loss claims.

REHABILITATION: POLICY AND PRACTICE

The council would like to see the Workmen's Compensation Board adopt a leadership role in the direction and financing of rehabilitation programs for the hard of hearing. The board's policy on rehabilitation is twofold:

- When a person is eligible for medical aid, he may be fitted with a hearing aid; and

- When a person is eligible for a pension for hearing loss, he may receive aural rehabilitation if a medical specialist so recommends.

It can be said that a person with noise-induced hearing loss loses hearing so gradually that he learns to live with the handicap by himself. The council is convinced that this argument does not deal adequately with the human problems of daily living which the hard of hearing may suffer. They can learn to cope with these new problems through instruction on how to use their residual hearing to best effect, how to lip read, and how to use the technological aids which may help them communicate more effectively.

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*the OHIP rate plus 10%

The WCB has already partially funded a pilot project at Laurentian Hospital to assist those suffering occupationally induced hearing loss. The instructors had to add this task as evening work in addition to their own duties, yet there were more clients than the project could instruct. The council believes that this type of project requires organizational direction and support. By their very nature, these short-term courses must be provided at a location close to the client's workplace or home.

RECOMMENDATION ACOHOS 79-35/Minister's response p. 123

That the minister encourage the Workmen's Compensation Board to continue to foster and support other pilot projects for aural rehabilitation similar to that offered by Laurentian and Mount Sinai hospitals.

The groups most likely to have the requisite skills are speech thereapists and audiologists. Speech therapists are in short supply at the moment, with a supply of about 375 compared with an estimated current need for about 460. Distribution of services also remains a problem. However, this group is much larger than the 60 or so audiologists in the province.[35] As appropriate manpower is limited, organization and financing become most important. The council believes that the Workmen's Compensation Board should take the initiative to ensure that adequate aural rehabilitation services are available in the province to serve its clients. This should extend beyond supporting pilot projects, because there is no concerted effort to organize aural rehabilitation programs for those suffering from noise-induced hearing loss. They are a minority within the total community of the hard of hearing which is itself served by an inadequate rehabilitation program.

In the council's view the board has a special responsibility to assist people with noise-induced hearing loss to function as normally as possible in society. This means that the 15% of workers with a 25 dB or more hearing loss who could require 40 hours of lip-reading classes and the additional 5% who may need a six-week course on lip reading, sign language and psychological counselling are not being adequately served.[36] Since 20% of medical aid and pension cases require this form of rehabilitation and the programs are not available on a province-wide basis, the council believes the board should adopt a leadership role in working with voluntary organizations and other groups who may wish to develop rehabilitation programs for the hard of hearing. The board's major contribution should be to support financially these rehabilitation programs until such time as they can become self-supporting.

RECOMMENDATION ACOHOS 79-36/Minister's response p. 123

That the Minister of Labour encourage the Workmen's Compensation Board to expand its rehabilitation program for the hard of hearing by making use of all available groups, including voluntary organizations, to establish aural rehabilitation programs.

The Canadian Hearing Society may offer good potential in providing province-wide rehabilitation programs. It could serve to mobilize the local expertise. The society has 10 regional offices located throughout Ontario and rehabilitation is its forte. While the society is one organization which has come to the council's attention, it is not the only group the board should consider in its attempt to improve rehabilitation services for the hard of hearing. This would serve to enhance the quality of life of the hard of hearing.

CONCLUSION

One of the most significant themes running through this report is the importance of an adequate information base for decision-making. In the absence of first-rate evidence it places decision-makers in the position of acting in the face of known uncertainty. The council accepts the present limits to knowledge in this field and has recommended that more research be carried out in several areas. Nonetheless, it also accepts the need to control sound levels at work. It believes this is one of the largest occupational health problems confronting Ontario, largely from the standpoint of the numbers of employees at risk and the costs to control the hazard. Only in the future when an adequate information base is developed will it be possible to conduct a proper economic analysis of the benefits to be achieved by the policies put forward in the areas of prevention, compensation and rehabilitation. The council believes that in the short term its recommendations could result in significant improvements in the light of present knowledge.

Footnotes

1. W. Burns, R. Hinchcliffe and T. Litter, "An Exploratory Study of Hearing and Noise Exposure in Textile Workers," *Annals of Occupational Hygiene* (vol., 17, 1964), 323-333.

2. Information provided to the council by Esso Chemical Canada Ltd., and Ontario Hydro.

3. American Academy of Ophthalmology and Otolaryngology, *Guide for Conservation of Hearing in Noise* (Rochester, Minn., 1973), p.14.

4. *Ibid.*, p.14.

5. U.S. National Institute for Occupational Health and Safety, *National Occupational Hazard Survey* (Rockville, Maryland, 1974), vol. III, table 49, p.290; and U.S. Department of Labor, Bureau of Labor Statistics, *Employment and Earnings, United States, 1909-1975* (Washington, D.C., 1978). There is evidence from surveys indicating that 14% to 18% of the labour force in manufacturing may be exposed to 90 dB(A) or more. See T. Cummings, "Effects of Noise on Hearing: Two Group Studies" (Toronto: University of Toronto, M.Sc. Thesis, 1976), p.55.

6. R.K. Miller and Associates, *Industrial Noise* (Atlanta, 1976), table 1.1, p.7.

7. American Academy of Ophthalmology and Otolaryngology, *Guide for the Conservation of Hearing in Noise* (Rochester, Minn., 1969), p.24.

8. Ontario Ministry of Labour, *Annual Report 1977-78* (Toronto, 1979), pp.18-19.

9. A great surge in claims and awards for hearing loss followed changes in the basis of compensation in 1974. For the first time employees were permitted to receive a pension while remaining exposed to noise.

10. There are still many claims not yet finalized and not included in the statistics.

11. Cummings, p.78, table 5 and confirmed by data supplied to the task force on a confidential basis by audiometric testing companies and industry.

12. International Organization for Standardization (T 80), *Recommendation R 1999: Assessment of Occupational Noise Exposure for Hearing Conservation Purposes* (Switzerland, 1975), p.6 indicates that 8% of workers at age 48 after 30 years exposure to 85 dB(A) could experience a 25 dB hearing loss in the speech frequencies (500, 1000, 2000 Hz) compared with 18% of workers exposed to 90 dB(A) for 30 years.

13. W.L. Braughn, *Relation Between Daily Exposure and Hearing Based on the Evaluation of 6,835 Industrial Noise Exposure Cases* (Springfield, Va: National Technical Information Service, 1973), p.21;
the percentage of the population exposed to 90 dB(A) that will exceed a 25 dB average loss criterion range from 2% to approximately 29% according to A. Suter and H.E. Von Gierke, *Evaluation of Compensation of Occupational Hearing Loss in the United States* (Springfield, Va.: National Technical Information Service, 1976), p.365; B.L. Lempert, *Occupational Noise and Hearing, 1968-1972* (Cincinnati, 1973), figures 10, 16, 17, 18, 19, pp.42, 48-51 respectively;
U.S., NOISH, *Occupational Exposure to Noise: Criteria for a Recommended Standard* (Washington, D.C.,1972), table XVII. See also U.S. Environmental Protection Agency, *Public Health and Welfare Criteria for Noise, July 27, 1973* (Washington, D.C., 1973). American Academy of Ophthalmology and Otolaryngology, *Guide for Conservation of Hearing in Noise* (Rochester, Minn. 1969), p.21, table IV.
The British research into occupational noise-induced hearing loss is extensive and differs from the work done by NIOSH in the United States: U.S., NIOSH, *Occupational Exposure*, pp vi and 31-33; British Occupational Hygiene Society, *Hygiene Standard for Wide-Band Noise, July 1971* (Oxford, 1971), pp. 7-8;

W. Burns, *Noise and Man* (London, 1968);
D.W. Robinson, "Estimating Risk of Hearing Loss due to Exposure to Continuous Noise," in *Occupational Hearing Loss Proceedings*, ed. D.W. Robinson (London, 1971), pp. 60-62; W. Burns and D.W. Robinson, *Hearing and Noise in Industry* (London: HMSO, 1970); and Department of Health and Social Security, *Occupational Deafness, A Report by the Industrial Injuries Advisory Council* (London, 1978), p.29.

14. W. Dixon Ward and A. Glorig, "Exhibit 1: A Critique of Research Data Relating Hearing Level to Exposure to Noise Below 90 dB(A)," *Journal of Occupational Medicine* (vol.17, no. 21, Dec. 1975), 776-770, and D.W. Robinson and M.S. Shipton, *Tables for the Estimation of Noise-Induced Hearing Loss* (Teddington, U.K. 1977), p.2.

15. See NIOSH, *Criteria Document*, Table XVII and Lempert, Figures 18 and 19.

16. R.A. Yerg, *et al.*, "Inter-Industry Noise Study," *Journal of Occupational Medicine* (vol. 20, no.5, 1978), 358.

17. Bureau of National Affairs, *Occupational Health and Safety Reporter* (vol.5, No.32, Jan.8, 1976), 1059 (vol.5, No.35, Jan.29, 1976), 1173, and (vol.6, No.1, June 3, 1976), p.8.

18. See for example J.D. Webb ed., *Noise Control in Industry* (New York, 1976); V. Salmon, J.S. Mills and A.C. Petersen *Industrial Noise Control Manual* (Cincinnati: U.S., NIOSH, revised edition, 1978); United Autoworkers of America, *Noise Control of: A Worker's Manual* (n.p.,1978); and D.M. Lipscomb and A.C. Taylor, *Noise Control: Handbook of Principles and Practices (New York, 1978).*

19. Germany, Construction Industry Accident Insurance Assn., *Regulation for Prevention of Accidents Noise* - Valid Dec. 1, 1974, para 4 (1).

20. R.K. Miller and Associates, Inc., *Noise Control Solutions for the Metal Products Industry* (Atlanta, 1977);
Forging Industry Educational and Research Foundation, Noise Project Task Force, *Engineering Guidelines to Forging Noise Control* (Cleveland, 1977); and
American Foundrymen's Society, *State-of-the-Art Noise Control for Chipping and Grinding, Combustion Electric Arc Furnaces, Shakeout, Molding Operations* (Des Plaines, Ill., 1978).

21. U.S., NIOSH, *Criteria Document*, p. vi - 34.

22. Research conducted by Dr. P.W. Alberti, University of Toronto and Mount Sinai Hospital; see also R.H. Campbell, "Selected Topics Concerning Hearing Protectors," *Proceedings of Canadian*

Conference on Personal Protective Equipment (Toronto, 1978), pp.9-11 and 13-14 and American Academy of Opthalmology and Otolaryngology, *Guide for Conservation of Hearing in Noise* (Los Angeles, 1964), p.18 and G.R.C. Atherley, "Noise", in *Industrial Safety Handbook*, ed. W. Handley (London, 1977), pp.343-346.

23. Draft terms of reference of Associate Committee on Noise Reduction of NRC.

24. Ontario Ministry of Health, *Occupational Audiometric Testing Programmes. Recommended Standards and Guidelines* (Toronto, 1974).

25. See for instance the American Council of Otolaryngology's criteria for referral to a specialist. The council recommends that employees should "be referred to a specialist for a possible hearing problem if audiological testing shows a change from a previous audiogram of more than 15 dB at 0.5, one and two kHz, more than 20 dB at three kHz, or more than 30 dB at four or six kHz. . . ." Bureau of National Affairs, *Occupational Health and Safety Reporter* (vol.8, no. 51, May 17, 1979), 1765-1766.

26. Ontario Ministry of Health, *Health Manpower in Ontario, 1978* (Toronto, 1978), p.7.

27. Royal Commission on the Health and Safety of Workers in Mines, *Report* (Toronto, 1976), p.233.

28. *Ibid.*, p.234.

29. Suter, pp. 363 and 365.

30. Workmen's Compensation Board of Ontario, "Guidelines for Adjudication of Industrial Noise-Induced Hearing Loss and Tinnitus Claims," Minute 17, June 12, 1979, p. 4797.

31. *Idem.*

32. Suter, *op. cit.*

33. P.W. Alberti *et al*, "Percentage Hearing Loss: Various Schemes Applied to a Large Population with Noise-Induced Hearing Loss," in *Effects of Noise on Hearing*, ed. Donald Henderson, *et al.* (New York, 1976), pp.479-496; and P.W. Alberti, "Audiology and Audiological Medicine," in *Compensation: Practice in Canada*, ed. H. Beagley (London, 1979).

34. Bureau of National Affairs, *Occupational Health and Safety Reporter* (vol.8, no.51, May 17, 1979), 1765.

35. Ontario Ministry of Health, *Manpower, 1978*, pp.3 and 163.

36. Dr. M.A. Haley, "Occupational Deafness," *Proceedings of Canadian Conference on Personal Protective Equipment* (Toronto, 1978), pp.12-13.

Acknowledgements

The Advisory Council on Occupational Health and Occupational Safety selected the membership for the task force from among its own members. These were Mrs. N. Caldbick (Chairman), Mr. L. Heard and Mr. D. Stover. It sought the Minister of Labour's assistance in appointing three experts in the field — Mr. R. Allen, Dr. P.W. Alberti and Dr. H. Pearsall. The contribution of Mrs. M. Kewin as liaison with the Joint Consultative Committee of Workmen's Compensation Board is also acknowledged. To supplement their own knowledge, the task force consulted a number of individuals and organizations. It wishes to express its appreciation to the following:

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Mr. P. Falkowski and Mr. K. Rothney - United Steel Workers of America
Mr. F. Young - Boilermakers Union
Mr. H. Kobryn - Provincial Building and Construction Trades Council of Ontario
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Mr. R. Nelson - Industrial Audiometry Services Ltd.
Mr. W. Ruth - Hearing Measurement Company Ltd. Conservation Consultants
Mr. E. Sone - Hearing Conservation Consultants
Mr. J. Johnson - Imperioal Oil Ltd.
Miss P. Brown - MDS Health Care Services

Glossary

A-weighted Sound Level dB(A) The ear does not respond equally to frequencies, but is less efficient at low and high frequencies than it is at medium or speech range frequencies. Thus, to obtain a single number representing the sound level of a noise containing a wide range of frequencies in a manner representative of the ear's response, it is necessary to reduce, or weight, the effects of the low and high frequencies with respect to the medium frequencies. The resultant sound level is said to be A-weighted, and the units are decibels (dB).

Audible Range of Frequency The frequency range of 20 Hz to 20,000 Hz, conventionally taken to be the normal frequency range of normal hearing.

Audiogram A chart, table, or graph showing hearing threshold level as a function of frequency.

Continuous Noise Ongoing noise, the intensity of which remains at a measurable level (which may vary) without interruption over an indefinite period or a specified period of time.

Deafness 100 percent impairment of hearing associated with an otological condition.

Dose Sound pressure level modified by time of exposure. *Loudness equivalent.*

Fence (slang) An arbitrary hearing level, greater than zero decibels, below which no hearing impairment is deemed to have occurred (low fence), or at which complete hearing impairment is deemed to have occurred (high fence), or at which administrative policy established hearing levels to adjudicate claims for hearing loss.

Handicap The occupational and sound difficulty experienced by a person with a hearing loss.

Hard of Hearing Having more than zero but less than 100 percent impairment of hearing for everyday speech or for pure tones of 500, 1000 and 2000 Hz.

Hearing Disability Hearing handicap prejudicing employment at full wages.

Hearing Impairment Hearing loss exceeding a designated criterion (commonly 25 dB ISO standard averaged from the threshold levels at 500, 1000 and 2000 Hz).

Hearing Loss Impairment of auditory sensitivity: an elevation of hearing threshold level with respect to the standard reference zero.

Hertz (Hz) Unit of measurement of frequency, numerically equal to cycles per second.

Impulse Noise Noise of short duration (typically less than one second) especially of high intensity, abrupt onset and rapid decay, and often of rapidly changing spectral composition.

Intermittent Noise Fluctuating noise, the level of which falls once or more times to very low or unmeasurable values during an exposure.

Loudness Equivalent (L_{eq}) The sound pressure level of a steady sound that has, over a given period, the same energy as the fluctuating sound in question. (Great Britain, Health and Safety Executive, *Audiometry in Industry: Discussion Document* (London, 1979).

Noise Exposure The integrated effect, over a given period of time, of a number of different events of equal or different noise levels and durations.

Noise-Induced Hearing Loss A sensorineural hearing loss caused by acoustic stimulation.

Presbycusis The decline in hearing that normally occurs as a person grows older.

Sound It may be described as a propagating disturbance through a physical medium. It is perceived by the ear as a pressure wave superimposed upon the ambient air pressure at the listener. (J. D. Irwin and E.R. Graf, *Industrial Noise and Vibration Control* (Englewood Cliffs, N.J., 1979), p. 1).

Tinnitus Ringing in the ear or noise sensed in the head.

Source: Except where indicated, the glossary was extracted from E.P.A., *Public Health and Welfare Criteria for Noise, July 1973* (Washington, D.C., 1973)

APPENDIX I

MEASURED NOISE LEVELS FOR SELECTED INDUSTRIAL OPERATIONS*

Textile Mill
1. loom - 106 dB(A)
2. cotton spinning - 83 dB(A)

Lumber and Wood Products
1. planer - 106 dB(A)
2. molder - 100 dB(A)
3. router - 93 dB(A)
4. shaper - 104 dB(A)
5. boring machine - 94 dB(A)

Furniture Products
1. cut-off saw - 112 dB(A)
2. sander - 97 dB(A)
3. radial arm saw - 98 dB(A)

Paper Products
1. paper cutter - 96 dB(A)
2. bag and handle former - 89 dB(A)

Printing and Publishing
1. newspaper press - 97 dB(A)
2. mona-casting - 91 dB(A)
3. postcard press - 91 dB(A)
4. keyboard mono-type - 84 dB(A)
5. offset press - 88 dB(A)
6. small offset press - 82 dB(A)
7. folding machines - 85 dB(A)
8. binder - 86 dB(A)

Petroleum Refining
1. can seaming - 96 dB(A)
2. furnace heating distilling columns - 100 dB(A)
3. steam let down - 130 dB(A)
4. furnace high speed rotating equipment - 100 dB(A)
5. furnace pumps - 103 dB(A)

Transportation
1. 1-ton truck - 70 dB(A)
2. 5-ton truck - 73 dB(A)
3. 20-ton truck - 92 dB(A)

*Noise measurements for the specified operations were taken from assorted Public Health Service surveys and references in acoustical and industrial hygienists' literature.

Glass Products
1. inflation of containers - 106 dB(A)
2. corrugated band saw - 99 dB(A)

Steel Products
1. coke oven - 83 dB(A)
2. blast furnace - 100 dB(A)
3. basic oxygen furnace - 91 dB(A)
4. electric furnace (150 tons) - 112 dB(A)
5. 160'' mill - 98 dB(A)

Various Metal Products
1. milling machine - 90 dB(A)
2. turret lathe - 90 dB(A)
3. 4'' hand grinder - 85 dB(A)
4. riveting machine - 110 dB(A)
5. forge drop hammer - 105 dB(A)
6. automatic punch press - 95 dB(A)
7. pneumatic chisel - 101 dB(A)

Canning Food Products
1. canning punch press - 97 dB(A)
2. can making body operation - 95 dB(A)
3. can filling machine - 100 dB(A)

Mining, Underground
1. axial vane fan - 107 dB(A)
2. stoper drill - 115 dB(A)
3. jackhammer drill - 113 dB(A)
4. roof bolter - 103 dB(A)
5. loader (gathering arm) - 96 dB(A)
6. conveyor belt - 93 dB(A)
7. continuous miner - 99 dB(A)

Mining, Open Pit
1. jumbo drill - 107 dB(A)
2. rotary drill - 93 dB(A)
3. crusher - 96 dB(A)
4. locomotive - 85 dB(A)
5. oxygen torches - 120 dB(A)

Heavy Equipment (earth moving)
1. double scraper - 92 dB(A)
2. scraper - 117 dB(A)
3. bulldozer - 110 dB(A)
4. road grader - 95 dB(A)

Farm Equipment

1. tractor - 98 dB(A)
2. grain roller mill - 85 dB(A)
3. pneumatic conveyor - 100 dB(A)
4. one-row beet puller - 94 dB(A)
5. two-row corn picker - 106 dB(A)

Source: U.S. NIOSH, *Occupational Exposure to Noise: A Criteria for a Recommended Standard* (Washington, D.C., 1972), Table VII.
See also Richard K. Miller and Associates Inc., *Noise Control Solutions for the Metal Products Industry* (Atlanta, 1977) which provides a useful summary of sound levels found in foundries and steel mills, and which provides approaches to sound control techniques for various types of equipment.

Ministry of Labour
Response to Advisory Council Memorandum 79-III, dated January 14, 1980

Occupational Hearing Loss: Prevention, Compensation and Rehabilitation

Note: The recommendations have been reordered and grouped under the following headings:

- Data Collection and Research
- Noise Regulation and Hearing Conservation Program
- Workplace Review and Program Development
- Compensation

The reordering was undertaken in order to better organize the Ministry's response.

DATA COLLECTION AND RESEARCH

RECOMMENDATION ACOHOS 79-20/For text see p. 85

> That, for the purposes of prevention, the Ministry of Labour periodically assess the appropriateness of the sound level standard adopted in Ontario and that there be established appropriate record linkage systems to collect local data relating actual individual sound exposures and audiometric monitoring results.

Response

Periodic Assessment of Exposure Limit

In proceeding with the development of a regulation for the control of worker exposure to occupational noise, the ministry has conducted an extensive review and assessment of the available options. Ministry staff will continue to monitor developments in this area. Where it is found

that data or developments in this field suggest the need for a possible adjustment to the hearing conservation program established in the province, further review of the appropriateness of the existing exposure limits will be conducted.

Record Linkage System

The compilation of further data relating to occupational hearing loss is recognized as being important for the development of an appropriate hearing conservation program in Ontario. The draft regulation for the control of worker exposure to noise, published in the *Ontario Gazette* in August, 1978, contains provisions for the maintenance of personal exposure records of workers exposed to hazardous levels of noise and will probably be retained in the regulation that is filed with the Registrar of Regulations.

As with other such medical records, employers will be required to make personal exposure records available for the review of the worker under surveillance and to the ministry for inspection. It has not been proposed, however, that employers be required to routinely report the details of these records to the ministry. As the council has noted, compulsory reporting would impose a cost burden on both industry and government, and would raise issues relating to the confidentiality of records. Opposition to data-reporting requirements also has been expressed repeatedly in submissions to the ministry in response to the Draft Regulation on Noise. However, since the reporting of personal exposure record data would be essential for the development of an easily accessible data system such as that recommended by the council, the question of compulsory reporting will have to be further considered.

RECOMMENDATION ACOHOS 79-25/For text see p. 94

> That the Ministry of Labour sponsor research on the actual individual noise exposure experienced by employees and, in particular, examine the actual sound levels experienced by employees on long work shifts and the effects of these levels on hearing.

Response

As noted above, the ministry will be requiring the maintenance of personal exposure records for workers exposed to hazardous levels of noise. Periodic surveys or reviews of these records will be conducted as part of the ministry's program for evaluating and monitoring the effectiveness of the regulation practices.

Sponsorship of additional research that will focus upon the effects of extended work shifts will be given consideration as the ministry further develops and refines its hearing conservation program.

RECOMMENDATION ACOHOS 79-21/For text see p. 92

> That the Ministry of Labour should sponsor ongoing research on the reduction of sound levels in machinery, and equipment where metal strikes metal.

Response

The ministry agrees with the council that the most effective and desirable solution to the problem of noise exposure in the workplace is the elimination of noise at the source through improved engineering controls. It also is recognized, of course, that extensive research and development in many areas of industrial design will be required to achieve this objective. The ministry certainly will encourage initiatives in this area. However, direct ministry involvement will be limited since primary responsibility for the financing and development of the engineering controls required in the workplace must remain with industry. Nevertheless, the ministry will seek to ensure that research of this nature receives the priority required in the industrial community.

RECOMMENDATION ACOHOS 79-26/For text see p. 95

That competent authorities work with manufacturers of equipment and machinery to reduce sound levels on new products, and that the Ministry of Labour along with other competent authorities work with the federal government to seek labelling provisions requiring machinery and equipment to have sound levels marked.

Response

As noted above, the ministry will encourage manufacturers to develop and produce improved equipment and machinery to reduce sound levels, although direct ministry participation will be limited.

The suggestion that the ministry consult with federal authorities to require the labelling of machinery and equipment indicating noise levels will be given consideration. A number of factors must be considered in assessing this recommendation, such as the difficulties involved in determining noise exposure resulting from specific equipment. The labelling of some equipment may provide a relatively simple and effective method of warning workers of noise hazards.

NOISE REGULATION AND HEARING CONSERVATION PROGRAM

RECOMMENDATION ACOHOS 79-22/For text see p. 92

That the Ministry of Labour adopt a regulation requiring:

- periodic measurement of sound in workplaces with 80 dB(A) or more,
- audiometric testing of employees exposed to four or more hours of sound at 85 dB(A) or more,
- employers to provide personal hearing protection devices where employees are exposed to 85 dB(A) or more,
- employers to reduce sound levels to 90 dB(A) by whatever means possible and, where this cannot be achieved, to require employees to wear personal protective hearing devices.

Response

This recommendation addresses four important elements of any regulatory strategy for the control of worker exposure to noise; the central feature being the recommendation for an eight hour exposure limit of 90 dBA.

As the council has noted, in attempting to establish such an exposure limit it is necessary to confront the complex questions relating to health risks and economic and technical feasibility. Each of these questions continues to be surrounded with considerable controversy and uncertainty. The council acknowledges that medical research indicates exposure to noise levels of 90 dBA can result in a greater risk of hearing impairment than occurs at 85 dBA and for this reason, argues that the reduction of noise levels to 85 dBA is a desirable long-term objective. However, the council concludes that it is not practicable at this time for many employers to attempt to achieve compliance with this lower level of occupational noise exposure.

The ministry acknowledges the council's concerns in this regard. The draft regulation on noise, published in August, 1978, proposed an exposure limit of 85 dBA for eight hours of daily exposure on the basis of medical research such as that cited in the council's memorandum. However, prior to formulating a final regulation for occupational noise exposure, the ministry will take into consideration the position adopted by the council which echoes the concerns expressed in many submissions to the ministry in response to the publication of the draft regulation. As a body representative of both employer and worker interests, the council's support of a 90 dBA limit at this time will be weighed carefully in the ministry's deliberations on this issue.

With regard to the remaining three parts of this recommendation, the ministry agrees in principle with the council's suggestion for a "staged sequence of required action." Specifically, the ministry agrees that it will be useful to ensure the periodic assessment of noise exposure in workplaces where workers are exposed to noise levels of 80 dBA or more. However, the periodic monitoring in all such workplaces may not be feasible. It also is agreed that audiometric testing of exposed workers is an important part of any hearing conservation program. However, as discussed in Recommendation 79-29, the ministry has not reached a final decision as to the details of a required audiometry program.

The third recommendation, that employers be required to make available hearing protection for voluntary use by employees exposed to noise levels below the prescribed limit, will be taken into consideration. The question of whether the use of personal hearing protection at noise levels of 85 dBA is voluntary or compulsory will depend, of course, upon the actual exposure limit adopted in the final regulation.

RECOMMENDATION ACOHOS 79-23/For text see p. 92

That the Ministry of Labour periodically assess the scientific and economic justifications for adopting a standard requiring employers to reduce sound to 85 dBA.

Response

The response to this recommendation also will be dependent upon the exposure limit adopted in the final regulation. As noted in response to Recommendation 79-20, the ministry will continue to monitor developments in the field of noise reduction and noise-induced health effects research to assess the appropriateness of the established exposure limit. The ministry will certainly review the possibility of reducing that limit to 85 dBA in the event that a limit of 90 dBA is adopted at this time.

RECOMMENDATION ACOHOS 79-29/For text see p. 96

That the Ministry of Labour require employers to provide initial screening audiograms within the first three months of employment for all employees exposed to 85 dB(A), or more, for four or more hours per day;

That the Ministry of Labour require employers to provide initial screening audiograms to all employees exposed to 85 dB(A), or more, for four or more hours per day; and

That the Ministry of Labour review and modify this policy if results of the program indicate there is a more reasonable pattern for administering audiometric tests.

Response

As noted in response to Recommendation 79-22, the ministry agrees with the recommendation for providing protective measures, such as audiometry, for workers exposed to potentially hazardous levels of noise. Provision for audiometric testing similar to that recommended, was included in the original Draft Regulation on Noise and will be included in the final regulation to protect workers sensitive to noise-induced hearing damage. However, in light of administrative costs involved in determining the actual duration of noise exposure for individual workers and the variability of individual susceptibility, it may be considered desirable to provide audiometric testing for all workers in workplaces where noise levels exceed a specified level, regardless of their period of exposure.

Any audiometric testing program established will be reviewed and modified where necessary in the future.

RECOMMENDATION ACOHOS 79-30/For text see p. 98

That the Ministry of Labour work with the Ministry of Colleges and Universities in developing a standardized audiometric technician training program across the province.

The council also endorses the recommendation of the Royal Commission on the Health and Safety of Workers in Mines, which suggested:

That the Occupational Health and Safety Branch regularly inspect all audiometric testing facilities not under the supervision of a

designated medical specialist, and that any designated medical specialist be required to certify biennially in writing that the facilities under his supervision conform to the minimum standards of the Ministry of Health as then current.

Response

The ministry recognizes the need to examine the availability and quality of training facilities for professional audiologists and audiometric technicians. In order to help ensure that adequate facilities are available in the near future, the ministry has requested that the Minister of Education/Colleges and Universities review this recommendation and consider the development of additional audiometric technician training programs in our post-secondary educational system.

RECOMMENDATION ACOHOS 79-31/For text see p. 98

That the Ministry of Labour ensure audiometric testing programs be carried out under appropriate professional supervision; and

That the Ministry of Labour establish a code of minimum practice, setting out minimum standards for (a) calibrating audiometric testing equipment, and (b) the permissible ambient sound level within a testing booth.

Response

Specification of the procedures and requirements for the conduct of audiometric testing were included in the draft regulation on noise and will be further developed if necessary for inclusion in the final regulation.

WORKPLACE REVIEW AND PROGRAM DEVELOPMENT

RECOMMENDATION ACOHOS 79-24/For text see p. 94

That employees be given the opportunity to participate in a hearing conservation program for the planning stages and, within approved types of equipment, employees be given a choice of the type of personal hearing protection equipment to be used on the job.

Response

In promoting the control of exposure to noise, as with all other occupational health hazards, the ministry will be emphasizing the need for worker participation in developing and implementing control strategies. Since noise will be designated as a substance hazardous to the health of workers, the establishment of joint health and safety committees will be mandatory for all workplaces where noise levels exceed the prescribed limit. Through these committees, it is envisaged that workers will be actively involved in the design and administration of hearing conservation programs, including the selection of hearing protective equipment.

Although it may not be feasible at some workplaces to allow individual workers a choice of hearing protective equipment, the ministry agrees that it may often be desirable for an employer to offer workers optional forms of protection.

RECOMMENDATION ACOHOS 79-27/For text see p. 95

That the Ministry of Labour encourage employers to adopt preventive maintenance programs to control sound levels.

Response

As noted in response to Recommendation 79-22, the ministry supports the council's position that sound prevention controls must play a central role in any hearing conservation program.

More explicit encouragement in this matter will be extended by ministry inspectors to all employers operating workplaces where noise levels could be reduced through effective preventive maintenance.

RECOMMENDATION ACOHOS 79-28/For text see p. 95

That the Ministry of Labour consider the feasibility of including a review of acoustical features when examining plans for new or changes in existing workplaces.

Response

Since noise has been clearly identified as a workplace hazard, worker exposure to noise is a factor that is taken into consideration in reviewing plans for new workplaces or changes in existing workplaces.

COMPENSATION

RECOMMENDATION ACOHOS 79-32/For text see p. 103

That the Minister of Labour consult with the Workmen's Compensation Board to consider appointing an independent committee of experts to investigate and make recommendations to the minister and the board on the basis of compensation for noise-induced hearing loss and, in so doing examine:

- the maximum limit of 30% total body disability for total chronic hearing loss;
- the rating scale used to determine the percentage of disability; and
- the criterion of 35 dB hearing loss used to determine a claimant's eligibility for a pension for noise-induced hearing loss.

RECOMMENDATION ACOHOS 79-33/For text see p. 103

That Minister of Labour ask the Workmen's Compensation Board to consider adjusting the disability rating for those with a 60 dB or greater binaural hearing loss on an interim basis.

RECOMMENDATION ACOHOS 79-34/For text see p. 104

That the Minister of Labour in consultation with the Workmen's Compensation Board and other appropriate government ministries develop and implement programs to ensure the availability of regional audiological facilities which are of a sufficiently high standard to allow effective and efficient adjudication of noise-induced hearing loss claims.

RECOMMENDATION ACOHOS 79-35/For text see p. 105

That the minister encourage the Workmen's Compensation Board to continue to foster and support other pilot projects for aural rehabilitation similar to that offered by Laurentian and Mount Sinai hospitals.

RECOMMENDATION ACOHOS 79-36/For text see p. 105

That the Minister of Labour encourage the Workmen's Compensation Board to expand its rehabilitation program for the hard of hearing by making use of all available groups, including voluntary organizations, to establish aural rehabilitation programs.

Response

A copy of Advisory Memorandum 79-III has been forwarded to the Chairman of the Workmen's Compensation Board for his review and comment. Since each of these recommendations either requires substantial involvement of the WCB or falls totally within the mandate of the board, further ministry examination has been deferred until these comments have been received.

APPENDIX H

SUMMARY OF PREVIOUS LEGISLATION

SUMMARY OF PREVIOUS LEGISLATION

Noise was regulated under The Industrial Safety Act, 1971, S.O. 1971, c. 43 as amended, in section 111. The provisions required mandatory hearing protection for sound levels greater than 115 decibels. Where the sound level was 90 decibels or greater, measures had to be taken to control the sound. Where such measures were impracticable then exposure had to be limited or hearing protection had to be worn. Also warning signs were required in areas where the sound level was greater than 90 decibels.

APPENDIX I

ORGANIZATIONS THAT RESPONDED TO THE PUBLICATION OF THE PROPOSED REGULATION, AUGUST 16, 1980

ORGANIZATIONS THAT RESPONDED TO THE PUBLICATION OF THE PROPOSED REGULATION, AUGUST 16, 1980

Abex Industries Limited
Canadian Brakeblok Division
50 Colborne Street East
Lindsay, Ontario
K9V 1K7

Ajax Precision Manufacturing Limited
37 Penn Drive
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Algoma Steel Corporation Limited
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N1H 6N1

American Industrial Hygiene Association
Ontario Local Section
P.O. Box 1232, Station 'Q'
Toronto, Ontario
M4T 2P4

Atlas Steels
P.O. Box 1000
Welland, Ontario
L3B 5A7

Automotive Parts Manufacturers' Association of Canada
55 York Street,
Suite 402
Toronto, Ontario
M5J 1R7

Bilsom International Limited
1 St. Clair Avenue East,
Suite 503
Toronto, Ontario
M4T 2V7

Borg-Warner (Canada) Limited
P.O. Box 10
Cobourg, Ontario
K9A 4K2

Morgan L. Brosnan, M.D.
131 Ontario Street
Suite 101
St. Catharines, Ontario
L2R 5K1

Butler Metal Products Company Limited
1574 Eagle North
Cambridge (Preston), Ontario
N3H 1C9

Campbell Soup Company Limited
Toronto, Ontario
M8V 2B8

Canada Alloy Castings Limited
529 Manitou Drive
Kitchener, Ontario
N2C 1S2

Canada Packers Inc.
95 St. Clair Avenue West
Toronto, Ontario
M4V 1P2

Canada Wire and Cable Limited
147 Laird Drive
Toronto, Ontario
M4G 3W1

Canadian Battery Manufacturers' Association
One Yonge Street
Toronto, Ontario
M5E 1J9

Canadian Chemical Producers' Association
350 Sparks Street
Suite 805
Ottawa, Ontario
K1R 7S8

Canadian Daily Newspaper Publishers Association
321 Bloor Street East
Toronto, Ontario
M4W 1E7

Canadian Diamond Drilling Association
c/o Bradley Bros. Limited
P.O. Box 485
Timmins, Ontario
P4N 7E7

Canadian Environmental Law Association
8 York Street,
5th Floor South
Toronto, Ontario
M5J 1R2

Canadian Federation of Independent Business
15 Coldwater Road
Don Mills, Ontario
M3B 3J1

Canadian Foundry Association
P.O. Box 2270
Orillia, Ontario
L3V 6S1

Canadian General Electric
1420 Dupont Street
Toronto, Ontario
M6H 2B2

The Canadian Hearing Society
60 Bedford Road
Toronto, Ontario
M5R 2K2

The Canadian Manufacturers' Association
1 Yonge Street
Toronto, Ontario
M5E 1J9

The Canadian Paint and Coatings Association
2050 Mansfield Street
Suite 800
Montreal, Quebec
H3A 1Y9

The Canadian Salt Company Limited
30 Prospect Avenue
Sandwich P.O. Box 7008
Windsor, Ontario
N9C 3Y7

Canadian Standards Association
178 Rexdale Boulevard
Rexdale, Ontario
M9W 1R3

Canadian Textiles Institute
1080 Beaver Hall Hill
Suite 1002
Montreal, P.Q.
H2Z 1T6

Canadian Tooling Manufacturers' Association
P.O. Box 2204,
Walkerville Postal Station
Windsor, Ontario
N8Y 4R8

Central Stampings Limited
2525 Central Avenue
Windsor, Ontario
N8W 4J6

Champion Spark Plug Company of Canada Limited
P.O. Box 910
Windsor, Ontario
N9A 6P2

Chrysler Canada Ltd.
Chrysler Centre
Windsor, Ontario
N9A 4H6

C.I.L. Inc.
C.I.L. House
P.O. Box 10
Montreal, P.Q.
H3C 2R3

Cliffs of Canada Limited
P.O. Box 877
Kirkland Lake, Ontario
P2N 3K7

Colgate-Palmolive Canada
64 Colgate Avenue
Toronto, Ontario
M4M 1N7

Confederation of Canadian Unions
1331½A St. Clair Avenue West
Toronto, Ontario
M6E 1C3

Construction Safety Association of Ontario
74 Victoria Street
Toronto, Ontario
M5C 2A5

Continental Can Company of Canada
P.O. Box 730, Station "K"
Toronto, Ontario
M4P 2W8

Continental Group of Canada Limited
111 St. Arnaud Street
Amherstburg, Ontario
N9V 2Y6

Council of Safety Associations (Ontario)
2 Bloor Street East,
20th Floor
Toronto, Ontario
M4W 3C3

Crown Cork and Seal Company Limited
7900 Keele Street
Concord, Ontario
L4K 1B6

Dayton-Walther Canada Limited
355 Silvercreek Parkway
Guelph, Ontario
N1H 1E6

Denison Mines Limited
Box B - 2600
Elliot Lake, Ontario
P5A 2K2

Dofasco
P.O. Box 460
Hamilton, Ontario
L8N 3J5

Dome Mines Limited
Mine Office
South Porcupine, Ontario
P0N 1H0

Dominion Forge Company Limited
2480 Seminole Street
P.O. Box 2070
Windsor, Ontario
N8Y 4R6

Domtar Chemicals Group
Sifto Salt Division
1136 Matheson Boulevard
Mississauga, Ontario
L4W 2V4

Domtar Forest Products
P.O. Box 480
Red Rock, Ontario
P0T 2P0

Dow Chemical of Canada Limited
South Vidal Street
P.O. Box 3030
Sarnia, Ontario
N7T 7M1

Duplate Canada Limited
First Avenue
Oshawa, Ontario
L1H 7L3

Dupont Canada Inc.
P.O. Box 5000
Kingston, Ontario
K7L 5A5

Eaton's
290 Yonge Street
Toronto, Ontario
M5B 1C8

Fabricated Steel Products (Windsor) Limited
850 Divsion Road
P.O. Box 1060
Windsor, Ontario
N9A 6P7

Falconbridge Nickel Mines Limited
Canadian Nickel Division
Sudbury Operations
Falconbridge, Ontario
P0M 1S0

Fiberglas Canada Limited
3080 Yonge Street
Toronto, Ontario
M4N 3N1

Ford Motor Company
The Canadian Road
Oakville, Ontario

Forest Products Accident Prevention Association
P.O. Box 270
North Bay, Ontario
P1B 8H2

General Motors of Canada Limited
215 William Street East
Oshawa, Ontario
L1G 1K7

General Wire and Cable Company Limited
P.O. Box 2009
Cobourg, Ontario
K9A 4M3

B.F. Goodrich Canada Limited
Executive Offices
Kitchener, Ontario
N2G 4J5

W.R. Grace & Company of Canada Limited
Construction Products Division
294 Clements Road West
Ajax, Ontario
L1S 3C6

Great Lakes Forgings (1974) Limited
1590 Mathew Brady Boulevard
Windsor, Ontario
N8S 3K6

The Griffith Laboratories Limited
757 Pharmacy Avenue
Scarborough, Ontario
M1L 3J8

Gulf Canada Limited
Box 460, Station 'A'
Toronto, Ontario
M5W 1E5

Hatch Associates Limited
21 St. Clair Avenue East
Toronto, Ontario
M4T 1L9

Hauser, Rontal, Rontal & Jacob
Associates in Otolaryngology, P.C.
21700 Northwestern Highway
#545, Tower 14
Southfield, Michigan
U.S.A., 48075

Hayes-Dana Inc.
The Weatherhead Division
109 Inkerman Street
ST. Thomas, Ontario
N5P 3G8

Health and Welfare Canada
Radiation Protection Bureau
Environmental Health Centre
Room 233, Tunney's Pasture
Ottawa, Ontario
K1A 0L2

Heath Survey Consultants (Canada) Limited
954 Leathorne Street
London, Ontario
N5Z 3M5

Hoffman Concrete Products Limited
604 Highway #17 West
Pembroke, Ontario
K8A 7G8

Holmes Foundry Limited
P.O. Box 970
200 Exmouth Street
Sarnia, Ontario
N7T 5M5

Honeywell Limited
740 Ellesmere Road
Scarborough, Ontario
M1P 2V9

Donald Hood
1265 East Arthur Street
#406
Thunder Bay, Ontario
P7E 6E7

Hull-Thomson Limited
3315 Devon Drive
Windsor, Ontario
N8X 4L5

IMC Chemical Group (Canada) Inc.
Industrial Minerals Divsion
P.O. Box 280
Havelock, Ontario
K0L 1Z0

Imperial Oil Limited
1 Duncan Mill Road
Don Mills, Ontario
M3B 1Z2

Inco Metals Company
Copper Cliff, Ontario
P0M 1N0

Industrial Accident Prevention Association
2 Bloor Street East
Toronto, Ontario
M4W 3C2

Industrial Audiometry Services Limited
92 Rutherford Road North
Brampton, Ontario
L6V 2J2

Kellogg Salada Canada Limited
6700 Finch Avenue West
Rexdale, Ontario
M9W 5P2

Kelsey-Hayes Canada Limited
Woodstock Division
P.O. Box 300
Woodstock, Ontario

Kodak Canada Inc.
3500 Eglinton Avenue West
Toronto, Ontario
M6M 1V3

Lear Siegler Industries Limited
General Seating Division
P.O. Box 758
530 Manitou Drive
Kitchener, Ontario
N2G 4C2

Maple Lodge Farms Limited
May Bros.
R.R. #2
Norval, Ontario
L0P 1K0

Barbara Menear
23 Glenelg Street West
Lindsay, Ontario
K9V 2T9

Mines Accident Prevention Association of Ontario
290 Second Avenue West
North Bay, Ontario
P1B 3K9

Ministry of the Environment
Pollution Control Branch
135 St. Clair Avenue West
Suite 100
Toronto, Ontario
M4V 1P5

Ministry of Transportation and Communications
Occupational Health and Safety Office
3rd Floor, West Tower
1201 Wilson Avenue
Downsview, Ontario
M3M 1J8

Monroe Auto Equipment Company of Canada
1400 - 17th Street East
P.O. Box 800
Owen Sound, Ontario
N4K 5Z9

Mount Sinai Hospital
Department of Otolaryngology
600 University Avneue
Toronto, Ontario
M5G 1X5

Nacan Products Limited
201 MacDonald Road
Collingwood, Ontario
L9Y 4J1

David Nailberg, M.D.
Abraham Crotin, M.D.
3000 Lawrence Avenue East
Scarborough, Ontario
M1P 2V1

National Auto Radiator Manufacturing
2575 Airport Road
Windsor, Ontario
N8W 1Z4

Non-Ferrous Founders' Society
P.O. Box 168
North Bay, Ontario
P1B 8H2

Noranda Mines Limited
P.O. Box 100
Manitouwadge, Ontario
P0T 2C0

Ontario Chamber of Commerce
2323 Yonge Street
Toronto, Ontario
M4P 2C9

Ontario Concrete Block Association
1013 Wilson Avenue
Suite 101
Downsview, Ontario
M3K 1G1

Ontario Concrete Pipe Association
2345 Stanfield Road
Suite 202
Mississauga, Ontario
L4Y 3Y3

Ontario Federation of Labour
15 Gervais Drive
Don Mills, Ontario
M3C 1Y8

Ontario Food Processors Association
2395 Cawthra Road
Suite 1
Mississauga, Ontario
L5A 2W8

Ontario Hydro
700 University Avenue
Toronto, Ontario
M5G 1X6

Ontario Meat Packers Safety Council
5233 Dundas Street West
Islington, Ontario
M9B 1A6

Ontario Medical Association
240 St. George Street
Toronto, Ontario
M5R 2P4

Ontario Mining Association
199 Bay Street
10th Floor
Toronto, Ontario
M5J 1L4

Ontario Occupational Health Nurses Association
3209 Rymal Road
Mississauga, Ontario
L4Y 3B8

Ontario Petroleum Association
2300 Yonge Street
P.O. Box 2383
Toronto, Ontario
M4P 1E4

Ontario Pulp and Paper Makers Safety Association
91 Kelfield Street
Rexdale, Ontario
M9W 5A4

Ontario Speech and Hearing Association
170 St. George Street
Suite 504
Toronto, Ontario
M5R 2M8

Ontario Trucking Association
555 Dixon Road
Rexdale, Ontario
M9W 1H8

H. E. Pearsall, M.D.
845 Regent Street South
Suite 204
Sudbury, Ontario
P3E 4T3

Pipe Line Contractors Association of Canada
698 Seymour Street
Suite 203
Vancouver, British Columbia
V6B 3K6

Port Weller Dry Docks
P.O. Box 3011
St. Catharines, Ontario
L2R 7C1

Queen's University
Occupational Health Resource Centre
25 Union Street
Kingston, Ontario
K7L 2N6

Reid Milling
27 Reid Drive
Streetsville Postal Station
Mississauga, Ontario
L5M 2B1

Reynolds Extrusion Company Ltd.
500 Edward Avenue
Richmond Hill, Ontario
L4C 4Y9

Rubber Association of Canada
100 University Avenue
Toronto, Ontario
M5J 1V5

A. G. Simpson Company Limited
675 Progress Avenue
Scarborough, Ontario
M1H 2W9

Society of the Plastics Industry of Canada
1262 Don Mills Road
Suite 104
Don Mills, Ontario
M3B 2W7

Sommerville Belkin Industries Limited
P.O. Box 5760
Station "A"
London, Ontario
N6A 4T2

Stelco Inc.
General Office
Stelco Tower
Hamilton, Ontario
L8N 3T1

Municipality of Metropolitan Toronto
Personnel Department
67 Adelaide Street East
Toronto, Ontario
M5C 1K6

Toronto Star Newspapers Limited
One Yonge Street
Toronto, Ontario
M5E 1E6

Toronto Transit Commission
1900 Yonge Street
Toronto, Ontario
M4S 1Z2

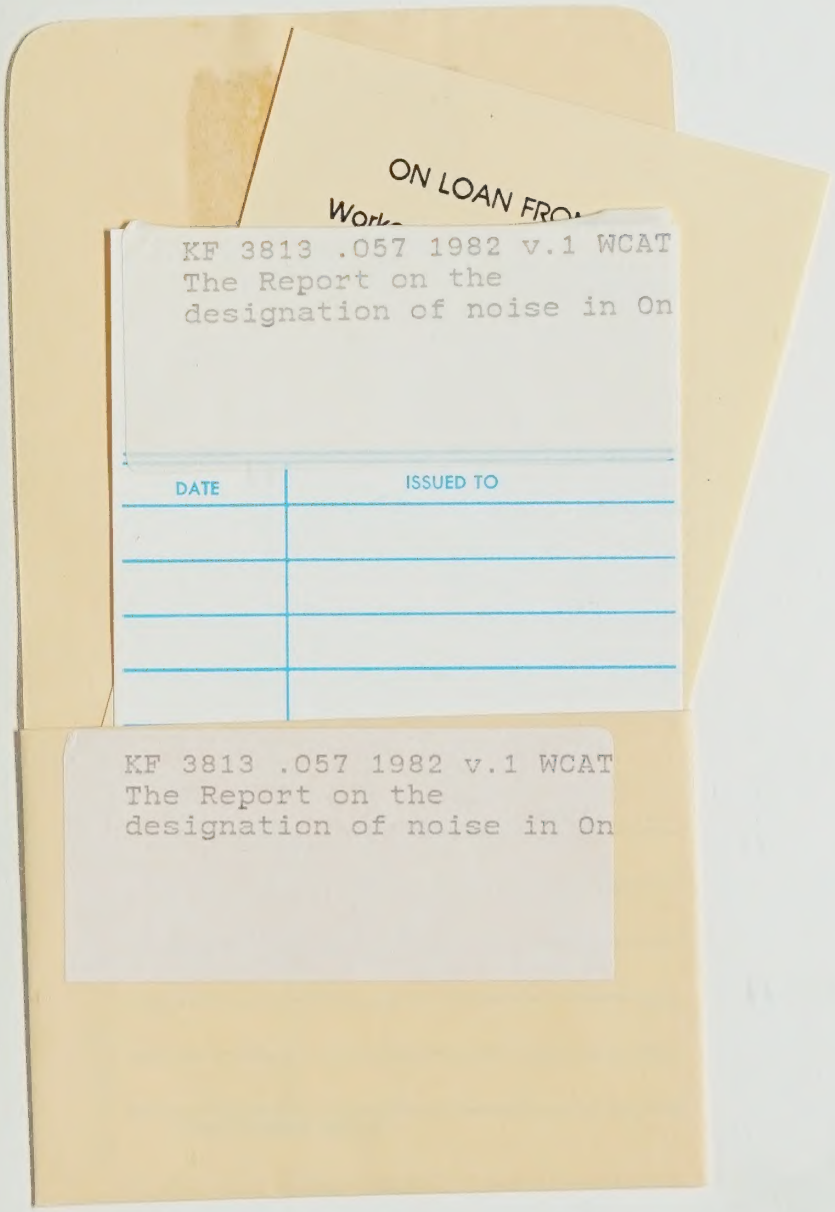
Union Carbide Canada Limited
123 Eglinton Avenue East
Toronto, Ontario
M4P 1J3

United Steelworkers of America
District #6
4th Floor, 100 Lombard Street
Toronto, Ontario
M5C 1L4

University of Western Ontario
Health Sciences Centre
London, Ontario
N6A 5C1

Welland Forge Division
P.O. Box 216
Centre Street
Welland, Ontario
L3B 5P4

Windsor Chamber of Commerce
500 Riverside Drive West
Windsor, Ontario
N9A 5K6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